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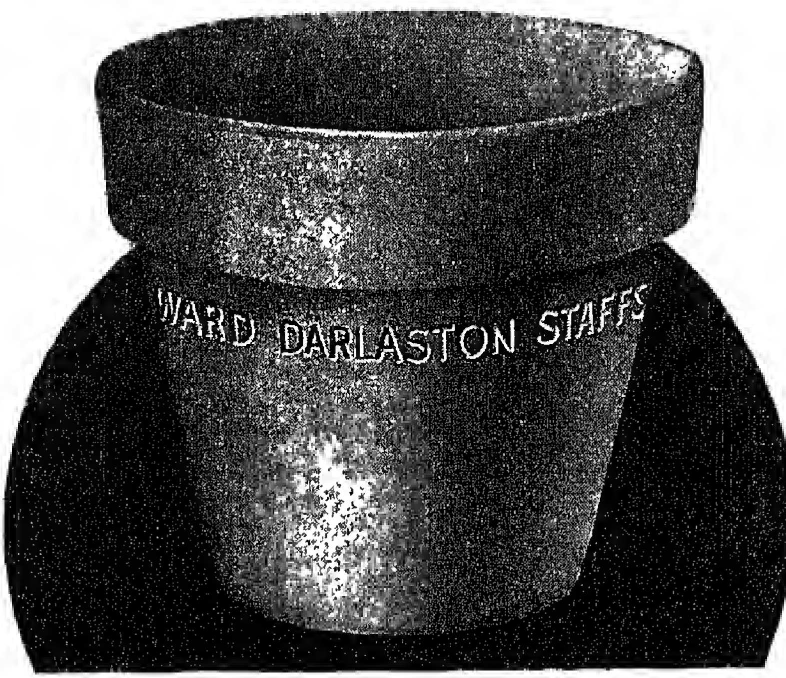

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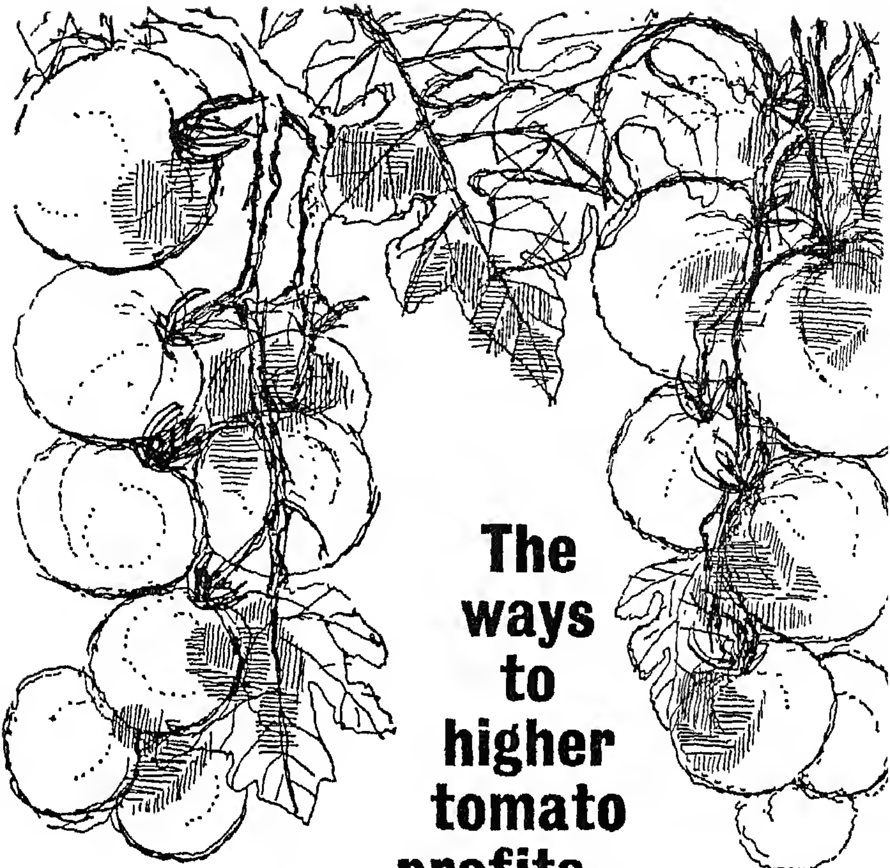

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MINISTRY OF
AGRICULTURE, FISHERIES AND FOOD

Tomatoes

Bulletin No. 77

DIVISION

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Foreword

TOMATOES are by far the most important of the crops grown in commercial glasshouses. The crop occupies some 2,000 acres in England and Wales and annual production is estimated at about 80,000 tons valued at £10 million.

This new edition of the bulletin has been made necessary by recent advances resulting from research and experimental work, particularly in the fields of temperature control and mechanization. The revision is the responsibility of the Glasshouse Group of the National Agricultural Advisory Service under the chairmanship of Mr. F. W. Toovey. Mr. R. Gardner has been mainly responsible for the new sections and general rearrangement. We are grateful to members of the staff of the Glasshouse Crops Research Institute, particularly Messrs. L. A. Darby and G. F. Sheard, for their help with several sections, and also to Mr. G. P. Shipway for the new section on equipment and mechanical aids.

The Ministry's Plant Pathology Laboratory is responsible for the information on pests and diseases. Mr. W. H. Read of the Glasshouse Crops Research Institute and Mr. C. A. Collingwood of N.A.A.S., Bristol, are thanked for their help with the revision of this section.

Ministry of Agriculture, Fisheries and Food
September, 1962

Contents

The Tomato Plant

THE cultivated tomato, *Lycopersicum esculentum*, is a member of the potato family, *Solanaceae*, and is indigenous to the lower western slopes of the Andes in South America. Several other species are also native to that region but they are of no direct commercial importance, although very valuable as the source of disease resistance characters for tomato breeding programmes.

Lycopersicum esculentum was first introduced into Italy in the middle of the 16th century and soon spread northwards into central Europe and to Britain. At this time it was known as the Peruvian, Golden or Love Apple and remained a curiosity or decorative plant for many years. During the 18th and 19th centuries suspicions about the tomato gradually receded and popular demand for it as an edible fruit increased. The considerable extension of its cultivation during the last ninety years has resulted in tomatoes which are now markedly different in fruit size and shape from the original introduction. Perhaps the most important change from the wild material has been that in the flowers of the English varieties the style is now completely enclosed within the anther cone. This ensures self-pollination, with the result that existing varieties (except for the recently developed F_1 hybrids) are all true-breeding inbred lines. The varietal characters come true from one generation to the next.

The ensuing brief botanical description refers only to those varieties which are usually cultivated under glass in Britain. Reference is subsequently made to other types (novelties, dwarf and bush varieties, etc., see p. 8) which play a minor role in crop production.

The tomato is a weak-stemmed herbaceous plant which under natural conditions forms a prostrate straggling bush. It behaves as an annual, though it will root readily along its stem and is capable of perennial growth. In most British varieties the habit of growth is indeterminate, i.e., the main stem extends indefinitely so long as growing conditions permit. The plant also branches readily, with the side shoot below each truss being very strongly developed. Below ground there is a weak tap root and an extensive fibrous secondary root system.

Leaf arrangement is alternate with a phyllotaxis of approximately one-third. The leaves are pinnate or bi-pinnate and the segments have a lobed or indented margin. In some varieties the leaflet margins are entire, giving a potato-leaf appearance. The plant bears hairs and glands which give it a characteristic scent when rubbed.

The inflorescences are lateral arising internodally, i.e., between the leaves. The first truss is usually produced after eight leaves, with subsequent trusses after every third leaf. The inflorescence is a cyme, although it is often modified to have two or more branches. In some conditions it may become leafy and continue vegetative growth.

Basically the flowers have six yellow petals and six sepals, though there may be more on fasciated blooms. The anthers, which are carried on very short stalks, are united to form a bottle-shaped tube. They open with a longitudinal split to shed their pollen inwards on to the stigma. The style is normally shorter than the anther tube, though in winter days the stigma

may protrude and lead to difficulties in setting fruit. The flowers are not normally visited by insects.

A few days after pollination the ovary, which is superior with axile placentation, swells to form the fruit which is a berry. This is red, shining and glabrous at maturity, with considerable variation in size and shape depending on the variety. The number of locules or chambers in the ovary is an important character. Bilocular ovaries give rise to round, two-chambered fruits, but ovaries with many locules result in large, ugly, multilocular tomatoes.

The buff coloured seeds, which average about 8,000 per ounce, are oval and flattened, the long diameter being approximately $\frac{1}{8}$ in. The cotyledons, which are coiled in the seed, are borne above soil level at germination.

Varieties

PERFORMANCE of varieties differs considerably from place to place and from year to year, and the impressions gained from cursory inspections of crops should not be allowed to delude growers into a hasty judgment on the merits or demerits of varieties. A reliable assessment of cropping behaviour can only be made after many years testing in properly conducted experiments and after extensive trials under practical conditions of growing and marketing. Growers should always be prepared in their own interest to try out new varieties, but they should do this on a small scale in one or two houses, *and over more than one year*. Trials over a single season can often be misleading and can result in ill-judged condemnation of a good new introduction or, as is equally likely, to a misplaced confidence in one of the "also rans".

Before considering the various characters in which varieties differ it is worth listing those people who are involved with the supply of tomatoes, together with the particular characters which concern them most directly.

1. Plant breeder.
2. Seed producer — ease of seed production.
3. Grower — low labour and heat requirements,
   ease of controlling vegetative growth and setting fruit,
   early yield,
   total yield,
   disease resistance.
4. Transporter — quality: firmness.
5. Salesman — quality: visual appearance — size, shape, colour.
6. Consumer — quality: flavour, texture.

People in the last three groups on the list have relatively few worries, but the grower has to concern himself not only with all those characters which involve him directly but also with those which influence the reactions of the transporter, salesman and consumer.

SEED PRODUCTION

Until 1950 all the tomatoes grown in Britain were true-breeding varieties. Seed of these is obtained by allowing the flowers to self-pollinate and, because they are adapted to this inbreeding mechanism, the varieties do not suffer from any genetic disorders as a consequence. Provided a variety has been correctly bred before its release, one generation will reproduce exactly (except for the very rare mutations or sports) the characters of its parents and pass on the same characters to its offspring. These varieties are often referred to as straight varieties and include Ailsa Craig, Moneymaker, Potentate and many others.

By comparison with the straight varieties there is an increasing number of F_1 or first-cross hybrids. These have been developed in the past ten years and result from the cross-pollination of two pre-existing straight varieties. As a consequence the F_1 hybrids exhibit certain characters from both parents. For example, the F_1 hybrid variety Ware Cross combines the heavier cropping of Potentate, the seed-parent, with an improvement in fruit quality due to the influence of the pollen parent, E.S.1. It is, however, very susceptible to *Cladosporium*. It was raised at the John Innes Institute and, in trials conducted at Experimental Horticulture Stations over a period of several years, has proved superior to Potentate in respect of early yield, total yield and fruit quality.

On no account should seed be saved from F_1 hybrids as they do not breed true; the progeny obtained by self-pollination vary considerably and result in very mixed plants.

To produce F_1 hybrid seed the anthers must first be removed from the flowers of the seed parent plant before they have split and shed any pollen. Subsequently pollen is collected from the pollen parent and transferred to the styles of the emasculated flowers. To meet the cost of these operations F_1 hybrid seed is usually about twice the price of seed of a straight variety, though this is still only a very small item in the total production costs of a tomato crop.

A seed company which develops an F_1 hybrid can regulate the total seed supply by retaining details of its parentage and so enjoy the consequent financial reward for the breeding work. The two existing British F_1 hybrids, Ware Cross and Hertford Cross, are obtainable as certified or uncertified seed. The former is preferable as the production of certified seed must conform to the standards laid down by the National Institute of Agricultural Botany.

It is important to realise that the merits of hybrid varieties must be judged by the same criteria as pure breeding varieties, and it must not be assumed that they possess any superior attributes merely because they are hybrids.

PLANT HABIT

Varieties differ considerably in growth and vigour though they can be classified into three basic types. These are referred to as compact, intermediate and tall, spreading habit.

Varieties in the compact habit group have restricted growth which results in plants with small leaves, shorter internodes and a less vigorous

root system. When conditions are favourable for strong vegetative growth it is easier to control these varieties, but in an adverse environment they will need careful attention in order to maintain satisfactory development. Baby Lea and Bonne Chose are varieties in this group.

Potentate is the best known example of those varieties with intermediate habit. The stature of these is between the other two types. Moneymaker is included in this group though it is a little more leafy than Potentate.

The tall, spreading group includes many varieties such as Ailsa Craig, E.S.5 and Ware Cross. These are typified by their very strong growth with large spreading leaves, long internodes and vigorous root systems. Where conditions are good the major problem with this group is to prevent lush vegetative growth and to promote fruiting.

It is important for the grower to choose varieties with potential growth that best suits his conditions and growing techniques. Generally for early heated crops on steamed soil the varieties of compact or intermediate habit are grown, though some experienced growers can control plants of the tall, spreading varieties very satisfactorily. The labour requirement for varieties differs considerably; much less is required for trimming and training compact plants than for tall, spreading plants.

TOTAL YIELD

The total crop weight from a given area of a variety depends on the number of plants per unit area, the number of fruits per plant and the mean weight per fruit. The first factor will be influenced by the plant habit discussed previously, with the compact habit types planted closer than the tall, spreading varieties. The number of fruits per plant depends on the number of trusses and the number of fruits per truss. Plants of compact habit bear many more trusses in a given height. Some varieties carry long, straight trusses with fruit borne regularly on either side of the single axis; this is the type found in Ailsa Craig and Harbinger. Sometimes these divide once to give a double truss. Other varieties, such as Potentate, carry trusses which often divide to produce two, three or even four short branches and so give the truss a square appearance. This type of truss is rarely constant on a plant and often the higher trusses are straight or only branched once. Truss characters and fruit numbers are, however, modified by temperature and light during development.

Mean fruit weight is determined by the number of locules and the weight per locule. Some varieties have mostly bilocular fruits, e.g., E.S.5, Moneymaker, Ailsa Craig and Harbinger, and of these Harbinger has smaller locules than Ailsa Craig. Other varieties are multilocular with two, three, four, five or even more locules per fruit. Such varieties as Potentate or Baby Lea have heavier fruit than the previous group, but always of poorer shape with more oval and ugly fruit.

EARLY YIELD

Many factors make up this very important character and, as these are mainly determined when the growing conditions are adverse, they are often the most variable and difficult to control. Days for germination, control of

vegetative growth, truss formation, flower development, pollen production, liberation and germination, fruit swelling and maturing all influence the time from sowing the seed to picking the first fruit. The following points indicate how these characters are influenced by other varietal features. Green stem varieties germinate a day or so before those with purple stems. For plant control in early crops a variety of compact or intermediate habit is usually preferable.

Varieties with bilocular fruits have better shaped flowers than the multilocular types. In the latter the fasciated blooms are often distorted, with a badly formed anther tube and the stigma exposed, and this may lead to pollination difficulties. Varieties with small fruits usually ripen more quickly than those with large fruits although of course it is the weight of early fruit which brings financial reward. The quickest ripening varieties do not usually have the heaviest total crops.

The green-back-free varieties mentioned later often seem to be slow to turn colour after they have reached full size. Potential is a variety which is very slow to mature.

DISEASE RESISTANCE

Although tomatoes are liable to attack by many pathogens, only resistance to leaf mould, *Cladosporium fulvum*, has been bred into modern varieties. The value of this work has often been nullified by the emergence of new genetic races of the fungus which can overcome the resistance of the plants. Accordingly, the behaviour of a resistant variety on a particular nursery will depend on the local race of the fungus. Varieties which incorporate resistance to certain races of leaf mould include Antimold A and B, Immuna, J.R.6, L.M.R.1, Syston Cross and Vetomold.

Among those varieties which are fully susceptible some variation in reaction exists. For example, Ailsa Craig suffers very much but by contrast Potentate is described as "field resistant", that is, the intensity of infection is less severe.

A new approach to the control of soil pathogens is the recently introduced grafting technique. The fruiting variety is grafted on to a special interspecific F_1 hybrid rootstock. By using particular parents for this F_1 hybrid, the rootstock can carry resistance to corky root as well as to *Didymella*, *Verticillium* and certain nematodes.

QUALITY

Firmness

Firmness and transportability are influenced by the internal structure of the fruit, i.e., by the number of locule walls, the thickness and rigidity of the outer wall and the fullness and turgidity of the locules. Each variety may well require its own method of culture in order to obtain firm fruit, for the larger the fruit produced in order to achieve heavy crops the lower its quality. E.S.5 is often spoken of as being very firm, but by contrast it is difficult to produce a really solid Harbinger under glass.

Size, Shape and Colour

These three characteristics seem to be interdependent, for the larger fruited varieties like Potentate and Baby Lea often include a higher proportion of fruit with inferior shape and colour. Smaller fruited varieties such as E.S.5, Ailsa Craig and Harbinger bear a very high proportion of round fruit with a much lower incidence of blotchy ripening.

Varieties may also be classified by reference to the disorder known as green back. Susceptible varieties have a dark green area around the stalk end of the fruit and, under some conditions, this remains hard and green or yellow even though the rest of the fruit is fully ripe and red. This must not be confused with many varieties in this group which have an overlay of dark green around the stalk, extending in streaks a little way round the cheeks of the fruit. As it ripens the lighter green turns red a day or two in advance of the darker area, but this is in no way detrimental to the quality of the fruit. A rare variant is sometimes seen in which the dark green overlay extends over the entire fruit which, in due course, ripens to a lurid dark red and is distinctly unattractive. Isolated plants of this type are occasionally seen in the variety Hundredfold.

The fruits of varieties which are not susceptible to green back have a uniform pale whitish-green colour when immature. They always colour evenly and never have the hard, unripe area around the calyx. These varieties include Moneymaker, Exhibition, Devon Surprise and Eurocross. It should be remembered that, although they are not susceptible to green back, under some conditions they may suffer from other colour ripening disorders.

Texture and Flavour

Personal tastes differ and there will always be controversy as to the best tomato for eating fresh. Ailsa Craig is favoured by many for its high acid and sugar content. Some people also enjoy its juiciness while others prefer the more fleshy Potentate, especially for slicing. The flavour of Moneymaker is often described as flat, while Sapford's No. 1 is commended for its thin skin.

The character exhibited by any organism results from the interaction of the inherited genetic particles with the environment. In the tomato the expression of varietal characteristics depends on soil, light, temperature, humidity, watering, feeding and many other factors which can be manipulated by the grower. Accordingly it is difficult and undesirable to be dogmatic about the behaviour of varieties without reference to growing conditions. However, from experience the average expressions of some characters of certain varieties are known and are shown in tabular form below. These varieties are listed in order of popularity; the first four varieties account for about 70 per cent of the total acreage of the tomato crop.*

* Based on a survey of varieties grown in 1959, carried out by the Agricultural Improvement Council. See Rep. Glasshouse Crops Res. Inst. 1959.

Variety	*Seed production*	*Habit*	*Earliness*	*Total yield*	*Fruit size*	*Fruit shape*	*Fruit colour*	*Green back*	*Cladosporium*
Moneymaker	S	I	L		M	R	G	F	
Potentate	S	I	L	H	L	OU	B	S	FR
Ware Cross	H	TS		H	ML	O		S	
Ailsa Craig	S	TS	E		SM	R	G	S	
Syston Cross	H	TS		M	ML	O		S	R
Carrick	S	TS			M			S	
J.R.6	S	TS			SM	R	G	S	R
Baby Lea	S	C	L	H	L	OU	B	S	
Antimold A	S	TS			M			S	R
Dutch Victory	S	I	L		M	R	G	F	
E.S.5	S	TS			SM	R	G	S	
E.S.1	S	TS			M	R	G	S	
Naftel's Discovery	S	I	L	H	L	OU	B	S	FR
Potential	S	TS	L	H	ML			S	
Hertford Cross	H	TS			ML	OU		S	R
Harbinger	S	TS	E		S	R	G	S	
Radio	S	TS	L		ML	R		S	S
Market King	S	TS			ML	R		S	S

Seed Production

S=True-breeding or straight variety
H=F_1 hybrid variety

Plant Habit

C=Compact
I=Intermediate
TS=Tall spreading

Earliness — This refers to the time of ripening of first fruit. It does not refer to early bulking.

E=Early to mature
L=Late to mature

Total Yield

H=Heavy cropper
M=Medium cropper

Fruit Size

S=Small
M=Medium
L=Large

Fruit Shape

R=Produces a high percentage of round fruit
O=Produces a percentage of oval fruit
U=Produces a percentage of ugly, badly shaped fruit

Fruit Colour

G=Usually of good colour
B=Very prone to blotchy ripening

Green Back

F=Non-susceptible to green back
S=Susceptible to green back

Leaf Mould

R=Resistant to certain races of *Cladosporium fulvum*
FR=Field-resistant

GROWING NEW VARIETIES

When testing new introductions it is important for the grower to follow the correct procedure in order to make accurate comparisons. During propagation and when planted the new variety should occupy a position away from the ends or sides of the glasshouse. If a hundred plants are being grown, mark off a hundred plants of the normal variety in an adjacent position and compare the two plots. Weigh the graded yields from the plots at each harvest and calculate the financial return from each variety, bearing in mind possible differences in production costs. Remember that with changes in culture the new variety may do better and bring higher returns than the old variety grown with the old technique. The grower must feel his way with a new variety until he learns how to exploit its inherited potential in order to get the optimum crop.

Novelty Colours

Although all our popular varieties have red fruit, other types exist with fruits which are pink, deep red, yellow, lemon, apricot, tangerine or golden striped. They could enhance many dishes but they are not cultivated commercially except the yellow fruited variety Golden Sunrise.

Dwarf and Bush Varieties

These are of no importance for use in glasshouses though they are suitable for growing in the open and under cloches. Dwarf varieties are of indeterminate habit but with very short internodes. They are usually trained as a single upright stem. First-in-the-Field (syn. Premier, Q77 and Lilliput) is a dwarf variety.

The bush varieties are quite different in their growth, having a determinate habit like many American varieties. The truss terminates each shoot and growth is maintained by side branches. It is preferable to thin these out, but the plants are often allowed to grow unrestricted and to sprawl on straw. The trusses are close together with only one or two leaves between each. Fargo, Puck, Amateur and Dwarf Gem are bush varieties, the last named being non-susceptible to green back.

Other Species

The fruits of the red currant tomato (*Lycopersicum pimpinellifolium*) and the cherry tomato (*L. esculentum var. cerasiforme*) are red or yellow and quite

edible though the skins are tough. They are attractive either for decorating salads or for use in floral arts.

Other wild species such as *L. hirsutum, L. peruvianum* and *L. glandulosum* are used in breeding programmes. Their fruits are purplish-green at maturity and are not fit for eating.

Cultivation in Heated Glasshouses

CHOICE OF SITE

In choosing a site for a new nursery for tomato growing there are initially several points to be considered. The obvious ones are those influenced by geographical location such as hours of sunshine, fog incidence and atmospheric pollution, prevailing winds, rainfall and type of soil and drainage. In addition to these factors it is also important to take into account the scale of production and the type and proximity of market to be supplied. It is most unlikely that a site will be available which provides the best of all these conditions and the grower must decide which are likely to prove most important.

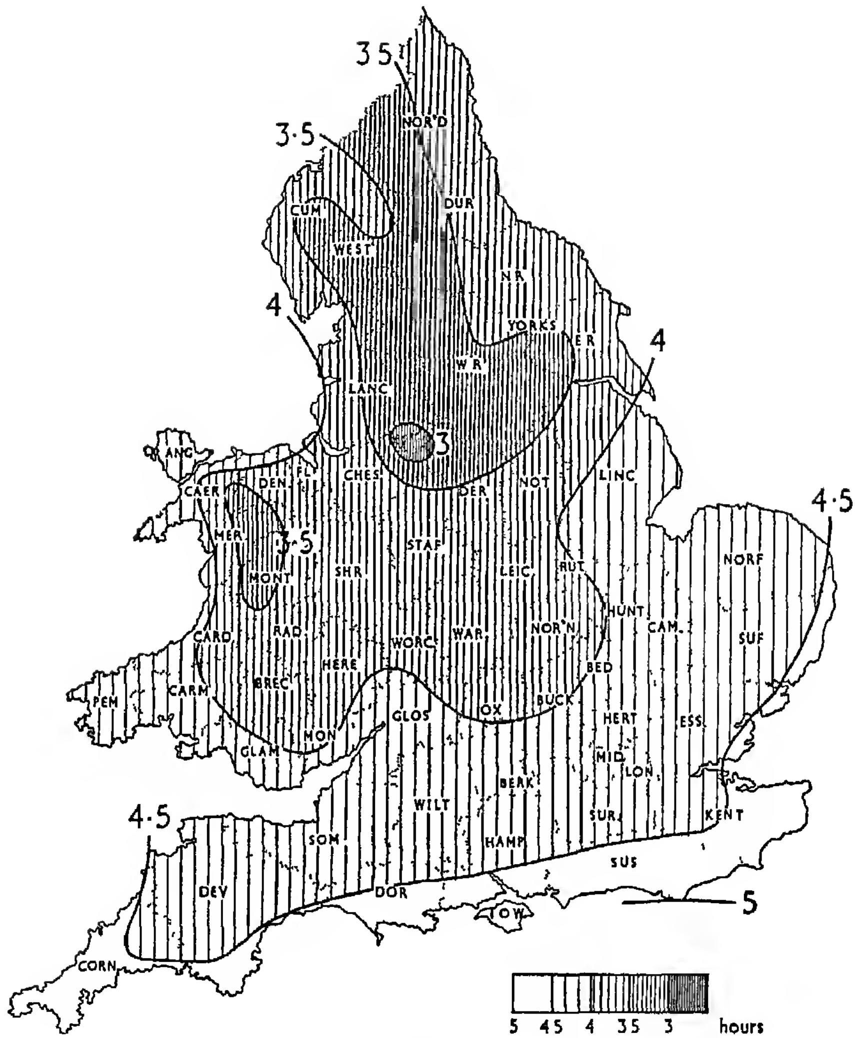
Sunshine

It has been established that, given a high standard of cultivation, the yield of tomatoes is related to the total sunshine hours during the period April to September. Recent research has shown that poor intensity and duration of sunshine within the glasshouse are factors which seriously limit the development in the winter period October to February. Good winter light is especially important for the satisfactory development of the young plants intended for early planting.

The daily average of bright sunshine taken over a whole year varies in the British Isles from nearly 5 hours per day on the extreme south coast to 3½ hours in the region of the Pennines. Map 1 shows the average number of hours per day of bright sunshine over the whole year for the British Isles, and Map 2 the average number of days per year with afternoon visibility of less than 4,400 yards. In general the best sunshine districts are on or near the coast and the poorest are those in hilly districts or within the atmospheric-pollution zones of large industrial or urban centres, the worst areas being on the leeside of the towns. The conditions may be further aggravated by deposits of soot and tarry matter on the glass. Rain will not remove it and the result is a permanent reduction in the light inside the house even when there is an improvement outside.

Local reductions in sunshine may also occur due to topographical features obstructing sunlight, especially in late autumn and early spring, on particular sites such as low-lying pockets in river valleys. These areas may also be subject to high humidity.

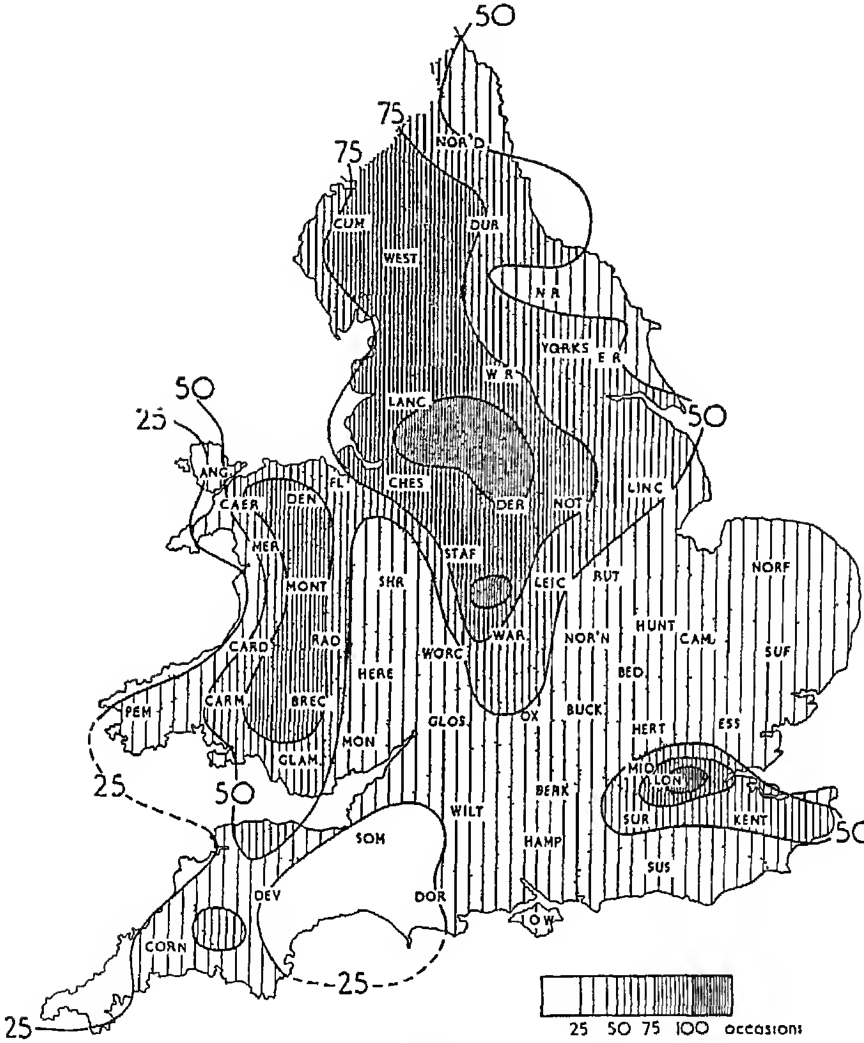
The need for care in the selection of a good natural site is of great economic importance for maincrop tomatoes, while for the profitable production of early fruit it is essential to select the best possible conditions.



MAP I
Average number of hours per day bright sunshine

Shelter

The best sunshine areas may also be areas of occasional high winds. Wind-pruned trees are a sure sign of prevailing winds of fairly high velocity and on such sites shelter is most desirable. Modern, well-designed glasshouses, even with large glass panes, are able to withstand strong winds, but the cooling effect of wind compared with still air rises steeply with the increase in velocity. Research has shown that a wind speed of 15–20 m.p.h. can double the heat consumption required to keep a glasshouse at a constant temperature. (See Report of Fairfield Experimental Horticulture Station 1959.) Appreciable savings of fuel, especially in the production of early crops, can be made by taking advantage of local topography and by the



MAP 2

Average number of days per year with afternoon visibility of less than 4,400 yards

establishment of a suitably sited shelter-belt. Details of the principles governing design and planting are given in Fixed Equipment of the Farm Leaflet 15: *Shelter Belts for Farmland**. For the protection of glasshouses and frames the most satisfactory shelter is that which filters the wind and thus reduces velocity. Solid obstructions cause violent turbulence which may do damage. A site offering shelter at the expense of sunshine should not be chosen, otherwise more will be lost than gained; increased temperatures can never substitute for a deficiency of natural light. Glasshouses should preferably be sited so that the skyline between SE and SW has an elevation not greater than 11 deg.

* See Appendix III.

Soil

The ideal soil is one of open texture which can be maintained in good physical condition in spite of the frequent watering necessary for high yields. It is worth while for a soil chemist to examine the site to determine the potential value of the soil for tomato growing, as it is uneconomic to bring an inferior soil into the right condition. Types of soil which nearly always lead to difficulties are thin soils over chalk or limestone, black organic soils, silts, poorly structured clays and any soils in which drainage is imperfect.

The natural drainage through the soil must be good. Where it is imperfect the plants are more prone to root troubles which lead to deterioration in the crop. It should also be noted whether any drainage water is received from neighbouring land, since in addition to the harmful physical effects this water may be a source of infection. Before selecting a site, samples of the soil should also be examined by a specialist for the presence of potato root eelworm and enquiries made to ascertain whether there is any history of trouble with root knot eelworm or verticillium wilt.

In some alluvial or marine soils situated in the flood plain of rivers or in areas affected by tides the water-table may rise and fall, and there is a danger that the roots may be drowned or toxic substances brought within their range. The soil may become wet in winter and sterilization may be difficult or impossible.

Slope

A level site is ideal for glasshouses. This allows the gutters and heating pipes to run level or nearly so. A slight slope to the south is permissible but this should not in any case be more than 1 in. in 10 ft, otherwise the cost of erection will be high owing to the necessity for levelling. In addition difficulties with temperature control and ventilation may arise. The site should have a level surface free from hollows and ridges which, if pronounced, also add considerably to building costs.

Public Services

A reliable water supply is essential and although water may be obtainable from public mains belonging to local authorities, sufficient water may not be available from this source if the nursery is to be comparatively large. The grower is advised to provide a storage tank and pumping plant so that his supply is not restricted at times of peak demand on the public mains. If an independent supply can be found underground this should be exploited.

Well-sinking is a specialized job and it is advisable to have it carried out by a reputable firm. Further details about wells, boreholes and pumps are given in Bulletin No. 138: *Irrigation.**

The Geological Survey and Museum will advise on the possibility of obtaining given quantities of underground water at certain depths on any particular site. Many conservation areas have now been defined under the Water Act 1945 and in these areas a licence to sink a well or borehole must be obtained from the Minister of Housing and Local Government. Drainage and Water Supplies Officers of County Agricultural Executive Committees

* See Appendix III.

will give information about conserved areas and the possibilities of proposals being grant-aided under the Farm Water Supply Scheme. Applications for grant must be approved before any work is started.

Electricity will also be required for such buildings as cottages, packing sheds and offices, and for working equipment used in the temperature control of the glasshouses and the heating system. A 3-phase supply should be obtained if possible.

Location

Planning permission may be necessary if it is intended to have a large nursery with substantial buildings and cottages. The project should be discussed with the County Planning Officer while still in the planning stage.

Labour

The labour requirement of the nursery must be considered as it is necessary to have at least five workers for each acre of tomatoes.

Marketing

The type and scale of production will naturally depend upon the type and location of the markets. On a small scale local sales may be made from the nursery or to shops in a nearby town and, provided the work is well organized and sufficient labour is available, these sales are often more profitable than wholesale marketing. For retail sales the choice of site is influenced very much by the market outlet and it is essential that the nursery should be sited in a position which will attract customers. For a nursery of this type the grower might attach more importance to the market outlet than to some of the factors discussed earlier.

When substantial quantities are grown, wholesale marketing is generally essential and transport then becomes an important item. It may be cheaper and more efficient for the grower to use his own motor vehicles. If a contractor is employed, the availability of service and time of day at which it can be obtained must be ascertained in advance. If the produce is to be sent by rail, the railway station should not be more than five or six miles away.

TYPES OF GLASSHOUSES

The class of house to be constructed will depend to some extent upon the requirements of the individual grower, but certain broad principles should be followed. In the past houses were often built primarily for tomatoes, but this is no longer desirable as flexibility of cropping is most necessary under present day conditions. With reasonable forethought it is possible to construct houses also suitable for lettuce, chrysanthemums, carnations and other flower crops grown in the glasshouse borders. In addition, these houses can be used satisfactorily for cucumbers provided any purlin posts are positioned with this in mind and the heating is adequate. Although a grower may not wish to produce the wide variety of crops listed, three or more types may be needed to provide the correct balance on the nursery.

Design

The highest yields are generally obtained from plants bearing the maximum possible numbers of trusses, so these multi-purpose houses should have

adequate head room with gutters about 6 ft in height. They should admit the maximum amount of light by the use of narrow bars and panes of glass at least 2 ft square. Heavy roof trusses should be avoided as these can obstruct the passage of light to the plants below. Growers have the choice of timber or light alloy for construction. On present costs the extra expense of light alloy is more than offset by lower maintenance cost compared with timber Clear span houses are readily obtainable in alloy and there have recently been developments which permit of a similar type of construction with timber.

Previously it has been common to build tomato houses in blocks ranging from 2–10 units. While this reduces the costs of erection and heating, large blocks are difficult to heat uniformly and ventilation in the central areas is inadequate during summer, giving poor temperature control which may lead to fruit ripening disorders. In addition, recent work at the Experimental Horticulture Stations has shown that the plants in the outer houses and across the ends of the block crop at a higher rate, which may be as much as 18 per cent above those growing in the inner areas. In view of this it may be worth building in smaller units and, although single houses are more costly to build and to heat, twin units with a minimum spacing of 6 ft between them might be an economic proposition. These will have most of the advantages, including flexibility of cropping, associated with single houses. They will also permit side and/or box ventilation to be installed and, though the latter can give trouble with draughts, work at the John Innes Institute has proved conclusively that they materially increase the efficiency of ventilation.

In a 30 ft wide house ventilators should be positioned on each side of the ridge and their total length should at least equal the length of the house. In warm districts and where houses are built in blocks it will be advantageous if ventilators are continuous on each side of the ridge, provided they open through an angle of 60 deg.

Ideally, in order to increase versatility and reduce labour costs by the maximum use of mechanical aids, the house should not have any purlin posts. With the newer methods of metal construction this is now practicable without the roof trusses having to be so heavy that they reduce light intake. In modern wooden houses it is possible to reduce purlin posts to the minimum and side stays can be omitted if rolled steel joists are incorporated in the walls. Clear span houses free from purlin support posts are now available in timber, the structure being strengthened with steel frames or tubular trusses.

Double doors wide enough for a tractor should be fitted in at least one end to facilitate the removal of crop remains, soil, etc., and the bringing in of manure and loam.

It has been shown that the tomato responds closely to the temperature regime adopted and an increase or decrease of a few degrees in the night temperature can materially affect early bulking, fruit quality and total crop. Thus it is essential that the heating system should be designed to give the minimum variation in time and space throughout the house or block. The trend towards the use of high-speed hot water in small diameter pipes makes for flexibility and, with a row of tomatoes on each side of the closed loops, there is benefit from the better micro-climate surrounding the plants in the early stages of growth. With pipes close to the soil the ground is warmer and air circulation around the plants is better. In the past it has been common

practice to build houses with a slight slope, but this increases temperature variations and can also be a nuisance with some types of automatic irrigation. If possible the houses should be level, but in any case a maximum fall of 1 in. in 10 ft should not be exceeded and it may even be worth while carrying out a certain amount of levelling before erection to obtain this by grading and removing the subsoil as required and replacing the top soil.

The following types of houses are used for the production of tomatoes (see Plates I and II).

Vinery Type

Vinery type houses are usually 28–30 ft wide, 5–7 ft to the eaves and gutters, 13–15 ft to the ridge and are built on brick or concrete walls 1–2 ft in height. Suitably stressed modern timber houses should only have two rows of purlin posts and with framed construction it is possible to have houses 30–42 ft wide with an unobstructed span.

Aeroplane Type

The aeroplane house, so called from its similarity to a hangar with high roof and relatively clear floor, has eaves and gutters at about 7 ft and a ridge at 12–13 ft. Each span is 14–15 ft wide and without purlin posts. Extra strength is given by cross-ties at right angles to the gutters and at gutter level. Ventilators are fixed alternately on either side of the ridge and it is claimed that this close and even distribution produces a more uniform temperature.

This type is still popular in Lancashire and the Clyde Valley but, although ventilation may be good and there is a 14–15 ft clear space suitable for tomatoes, lettuce and several other crops, the closeness of the gutters when the houses are built in blocks obstructs light intake and increases the initial cost of construction.

Guernsey Type

This is used in the Channel Islands and occasionally in England. The houses are usually 20–30 ft wide and up to 15 ft to the ridge. They have dwarf walls of about 1 ft and the slightly sloping sides are 5–6½ ft high. In Guernsey they are normally built as single or twin units. The construction is so arranged that there are no purlin posts, but this means a heavy roof truss which obstructs a certain amount of light.

Dutch Light Structures

Dutch light structures were first introduced from Holland and are the cheapest method of covering land for the production of tomatoes under glass. The houses can also be used for lettuce, or the lights can be transferred to frames for the production of other crops. These structures are still popular in certain areas for cool grown crops and there is a trend towards heating them to give the small temperature lift required by tomatoes at the beginning and end of the season.

Mobile Houses

The mobile glasshouse offers the opportunity of rotational cropping and provides a means of avoiding the ill effects on the soil that may accrue from

permanent coverage. Depending on the number of alternative sites provided, mobile houses can delay initially the need for soil sterilization and may reduce the frequency of this need later. It is virtually impossible, however, to provide sufficient alternative sites to enable a rotation to be practiced which is long enough to ensure the tomato crop being grown on trouble-free soil. With the few sites that are usually provided it soon becomes good policy to resort to soil sterilization as an insurance for a full crop. Mobile glasshouses, therefore, have few advantages for the specialist tomato grower, but they can be of great benefit to the intensive market gardener interested in cropping his houses with tomatoes during the summer months and anxious to change quickly from one crop to another. Growers interested in mobile houses should take advantage of the wide roof spans and permanent glazing which are a feature of up-to-date design. Large units relative to the size of the holding should be avoided.

Mobile houses are by no means new, but the idea of building a house on rails to run over wheels mounted on dollies, rather than attaching wheels to the house and running it over fixed rails, has stimulated fresh interest and given greater confidence in this type of house. In this country up to the end of 1954 the mobile glasshouse had developed as a steel framework covered with Dutch lights. It has now been demonstrated, however, that fixed glazing can be used successfully and has the advantage of giving less light obstruction. Several types with this form of glazing are now reasonably airtight and can be heated efficiently and economically for early and late crops.

With the great advances in design and the lowering of prices mobile houses are worth consideration. They have advantages over static houses or structures in that they can be utilized to cover more than one site and, in addition to giving scope for rotation of crops, labour may be saved and production increased by moving the house over another crop when the one previously covered is cleared.

Before constructing a mobile house it is necessary to ascertain that the area is sufficiently large and level to permit the traverse over more than one site, the actual number depending on the cropping sequence and land available. It must be remembered that the longer the house, within reason, the cheaper the cost at the outset. (See also Advisory Leaflet 465: *The Design and Cropping of Mobile Glasshouses**.)

Propagating Houses

The general practice is to propagate tomato plants in small span-roofed houses and when the plants are a few weeks old to space them out on temporary staging in one or more of the cropping houses. Recent work by W. J. C. Lawrence has shown that, for propagating purposes, single span houses built with moderately high sloping sides (at an angle of 65 deg. to the horizontal) and orientated east to west provide much better light transmission during the late winter and early spring months than a north to south house. By means of gussetted construction it is possible to do away with a gutter plate at eaves level and so allow the maximum entry of sunlight at a time of year when the sun is low on the horizon. This method need not increase the cost of erection and in some cases has been cheaper. Houses of this type have been built at several of the Experimental Horti-

* See Appendix III.

culture Stations and the trials so far indicate that the improved light produces plants of better quality with a higher crop potential in the first 5–8 weeks of picking. The transmission of light depends on the orientation, roof shape and proportion of glass to opaque structural material. The proportion of structural material should be kept to a minimum.

Full construction and heating details for all types of houses can be obtained from Bulletin No. 155: *The Construction and Heating of Commercial Glasshouses*.*

LAYOUT OF NURSERY

Although the layout of any individual nursery must be largely influenced by circumstances, the general underlying principles can be stated briefly.

Where development is contemplated the initial design should be such that it can proceed in an orderly and efficient manner. The chief considerations in layout are that the site for and orientation of the main houses and of the heating apparatus and chimneys should ensure that no shadows are cast on the houses and that the products of combustion are carried away by the prevailing winds. Propagating houses should be given the sunniest and most sheltered position because they will be in use during the winter and early spring. The shed for soil preparation and stacking of loam should adjoin the propagating houses. (See also Fixed Equipment of the Farm Leaflet 44: *Design of Horticultural Packing Sheds.*)*

A shed which is well lighted and large enough to house the sterilizing equipment, pots, seeds trays, etc., should also provide room for mixing composts and, where desired, the making of soil blocks. The entrance should be of adequate size and on the same level as the outside road to permit the ready entry of vehicles.

When tomatoes only are grown a north facing packing shed may be combined with the soil preparation shed, since the peak period of work on these two operations succeed each other conveniently. Storage for empties, packing materials, etc., may be provided in a loft above or in the roof. Good light should be provided for grading and packing and arrangements made so that the operations follow consecutively and a free flow of produce is maintained.

If pumping equipment and water are necessary on the holding they should be sited centrally to give efficient distribution to all the houses. Service roads, preferably of concrete, are necessary for the transport of fuel, loam, farmyard manure, plants and fruit. They should be at least 9 ft wide, with passing places where necessary, and provided with drains to take the surface water and water from the roofs of the glasshouses. The minimum radius for corners should be 30 ft.

PROPAGATION

The need for great care in the details of propagation work cannot be emphasized too strongly, for upon it depends the quality of the plants set out in the houses and in consequence the success of the crop. The young plants should be sturdy and healthy when ready for planting.

The chief aim in growing tomatoes in heated houses is to obtain an early

* See Appendix III

crop, and it has already been pointed out that for this purpose light is one of the most important factors, particularly during propagation. The siting, design and conditions of the propagating house are therefore of fundamental importance. It has been shown at the John Innes Institute that, in a single house running east-west to admit the maximum of available winter light, sowing can start a week later than in a similar house running north-south, and other conditions being equal the first fruits can be picked at the same time from both houses.

The houses should be thoroughly cleaned and disinfected during the winter and the inside of the superstructure thoroughly sprayed with formaldehyde at least 4 weeks before sowing. All boxes, pots and staging, if not new, should be treated similarly.

Seed and Potting Composts

Loam is the most important part of a compost and results will be unsatisfactory unless the right type is obtained. A suitable loam is one of medium texture which, if rubbed when moist between fingers and thumb, feels slightly greasy without being sticky. It should have a pH of about 6·3 and contain not more than 5–6 per cent organic matter.

Every effort should be made to have the soil analysed before stacking is done; it is then possible to add ground chalk, superphosphate or stable manure whilst the turves are being stacked in order to correct any deficiencies. These materials are agents in the improvement of the loam and are not to be regarded as ingredients of the compost. (See Advisory Leaflet 471: *Seed and Potting Composts* and Bulletin No. 22: *Soil Sterilization.*)*

For both seed sowing and potting the majority of growers now make up composts to the formulae developed by the John Innes Institute.

The seed compost (J.I.S.) is composed of 2 parts steam-sterilized medium loam, 1 part peat and 1 part coarse sand. To every bushel of compost are added 1½ oz superphosphate and ¾ oz ground chalk. For larger quantities of compost 2 lb superphosphate and 1 lb chalk are added to each cu. yd (20 bushels) of the compost.

The John Innes potting compost (J.I.P.) is composed of 7 parts steam-sterilized medium loam, 3 parts peat and 2 parts coarse sand. To every bushel of the compost are added ¼ lb J.I. base fertilizer and ¾ oz ground chalk. For larger quantities 5 lb J.I. base fertilizer and 1 lb chalk are added to each cu. yd of compost. The mixture is referred to as J.I.P.1, the figure relating to the inclusion of one dose or unit of the base fertilizer and chalk. Sometimes, however, a compost containing twice the amount of the base fertilizer and ground chalk is required and the compost is then termed J.I.P.2. Experiments have shown that for late sowing under good light conditions better crops have been obtained from plants grown in a J.I.P.2 mixture. It should also be used for all plants potted after March and for Potentate and related varieties from earlier sowings.

The J.I. base fertilizer is obtainable through the usual trade channels and is constituted as follows:

Parts by weight
- 2 parts hoof-and-horn, ⅛ in. grist (13 per cent N)
- 2 parts superphosphate (18 per cent P_2O_5)
- 1 part sulphate of potash (48 per cent K_2O)

giving an approximate analysis of nitrogen 5·1, soluble phosphoric acid 7·2 and potash 9·7 per cent.

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* See Appendix III.

Composts other than those made to the John Innes formulae are used by some growers and, provided that the mixture is free from harmful organisms, is in good physical condition and contains an adequate but not excessive supply of nutrients, good results are obtained. The use of old cucumber beds as composts cannot be advised. Such composts, rich in organic matter, release ammonia freely after steaming and damage to seedlings has often been noted where these have been used.

Seed Sowing

The date of sowing is timed to fit into a planned schedule for planting and cropping. For the earliest crops sowings are made from the end of October to early December. The main crop is usually sown in December–January, crops for cold houses are sown in late February–early March and for the open ground crop sowing is done in early April.

In midwinter, from early sowings in November and early December, with short days and light of poor intensity, the growth of seedlings may be weak and of poor colour unless the young plants are grown slowly by the use of moderate heat. Alternatively, supplementary illumination can be given to sowings made after the end of November (see p. 23). After February supplementary lighting should not be necessary except during dull periods or in smoky districts.

The seed is sown in seed boxes, normally measuring $14 \times 8\frac{3}{8} \times 2$ in. inside. The boxes are filled with compost which is struck off level and pressed down to within about $\frac{1}{4}$ in. of the top. The amount of pressure applied varies with the type of soil used, the heavier types being only lightly compressed. The soil should be watered before sowing and further watering is not usually necessary.

The seed is sown thickly, 250–300 per box, spacing it as evenly as possible and covering with a $\frac{1}{4}$ in. layer of seed compost passed through a $\frac{1}{8}$ in. sieve. If the covering is less than this the testa tends to come up with the seedling giving some risk of distortion and virus transmission. To conserve moisture the boxes should be covered with glass or polythene and shaded with sheets of paper.

(See Appendix I for guidance on quantities and space needed for plant raising.)

As a temperature of 65°F is best for germination the boxes are usually placed near the heating pipes, but the covering must be removed as soon as the seedlings begin to appear and the boxes placed in full light on the staging immediately the majority of the seedlings have emerged.

The seedlings are moved directly into $3\frac{1}{2}$ in. pots or soil blocks about 2–4 days after complete germination, or as soon as the seed leaves have fully opened (see Plate V). It is important to use pots of adequate size to ensure that the plants develop sufficiently prior to planting.

In order to encourage maximum development of the bottom trusses great care must be taken to provide suitable temperatures at this and subsequent stages of growth (see p. 21).

Methods of sowing and the procedure followed for potting off and pricking out vary. Investigations at the John Innes Institute have shown, however, that potting seedlings at a very early age, i.e., as soon as the seed leaves have fully expanded, results in increased yields during the first month of picking, a time when the prices should be high.

Potting

The large size 60 pot, $3\frac{1}{2}$ in. high with a diameter of $3\frac{1}{2}$ in. inside the top, is the most popular type of clay pot for tomatoes. Pots should be well made and free from salt. The latter point is important for serious damage has been traced to this fault in consignments from some districts. New pots should be soaked in water for at least 12 hours before use, and those which have been used previously should be cleaned thoroughly and sterilized by boiling, steaming or treatment with formaldehyde. After the latter treatment they must be quite dry before use. Sterilization is necessary because disease can be carried from season to season by means of the pots. Pots made from bitumenized fibreboard can also be used and as they are not used again the need for storage and sterilizing and the loss from breakages are eliminated.

For early plantings clay pots possess advantages over soil blocks. It is an advantage to hold these plants to a more mature stage before planting and this involves liquid feeding and careful watering, such treatment being more readily given to plants in pots.

There are various methods of filling pots, for example shovelling the soil loosely into a batch of pots in a tray and levelling off, or filling into the individual pots by scooping soil from a nearby heap on the bench, either completing the filling in one movement or topping up later with more soil as part of the actual planting operation. If the soil is in the right condition and the pot filled loosely, a smart tap on the bench or ground is often sufficient to settle the soil to the right depth and firmness, or the fingers may be used in firming.

Small batches of seedlings are removed from the seed box, taking care to preserve the roots intact as far as possible. The seedling to be planted should be lightly held by a seed-leaf and inserted in a hole made with the finger or small dibber, and finally firmed by the same means, or the pot may be lightly tapped on the bench to complete firming and levelling. In the finished pot the soil should be level and about $\frac{1}{2}$ in. below the top of the pot, the seed-leaves being about $\frac{1}{4}$ in. above the soil.

The finished appearance of a batch of plants reflects the skill of the worker and good work reduces the risk of trouble or failure later.

During potting economy of movement and speed depend on the pots, soil heap and seed boxes being convenient to the worker's hands. The movement of the two hands should be co-ordinated so that both are effectively employed during the whole operation of filling, potting and final disposal of the potted plant. The flow of pots and plants should follow an orderly pattern, so that each stage of the work ends where the next one begins; for example, a right-handed worker needs the seedlings to be near his left hand, the pots of soil immediately to the right and in front of him, and he disposes of the planted pots to his right on completion. Establishing a rhythm of repetitive movements contributes to ease and speed of working.

After potting water may be given to settle the compost round the roots, but discretion is needed. If the compost is moist enough watering may be unnecessary for two or three days, in which case an occasional light syringing with water is helpful.

The plants should stand in good light and not be overcrowded. If limitations of space necessitate close standing in the first place, this must not be for long; the plants *must* be spaced out at the earliest opportunity to

prevent them from growing spindly and competing with each other for light.

Usually all propagation work is carried out on slatted staging specially erected for the purpose, but in localities where the light is good and the pots dry out rapidly, better plants are produced if the pots are placed on or near the ground where they are cooler and require less watering. For this purpose a well-lighted house is essential, otherwise there is too much shade near the walls. In such cases the plants, after potting, should be kept "pot thick" on the staging for about ten days and then stood out on the ground, allowing them more room. This practice of standing on the soil should not be followed if there is any risk of infection from the base, particular care must be taken if there is any risk of symphylids being present.

Use of Soil Blocks

The use of soil blocks as an alternative to pots has become popular with many growers. These are made by pressing a suitably prepared compost into a block, a small depression being left in the centre for the reception of the seedling and a little additional compost. Correct soil texture is most important: if too light the block fails to hold together properly; if too heavy or the compost over-wet, excessive soil compression may occur and a "steely" surface result. Both conditions are bad for the development of the seedling.

The blocks are of various sizes but those commonly used correspond to 3½ in. (60 size) pots although they contain more soil, and this helps to compensate for the adverse effect of superficial drying out of the blocks in warm, dry weather. The prevention of drying out is very important as otherwise the stability of the block and growth of the plant suffer. The risk, however, is less serious at the normal propagating season which occurs in the early months of the year, and it can be kept under control by gentle rose watering during sunny periods. Early transfer of the seedlings to the soil blocks is essential, after which the seedlings should be watered in. Sometimes the soil blocks are placed in trays of wood or aluminium in order to reduce the risk of the sides breaking or of drying out. Eventually the block becomes filled with roots which hold it together. Whether placed on staging or in trays, a small space is left between the blocks to prevent them rooting together, but this space should not be large enough to allow them to dry out too quickly (see Plate V).

For main crops soil blocks give as good results as pots of the appropriate size and, provided they are properly made and managed, they are a suitable alternative, but they need to be made and planted on the premises. The greater bulk of soil in the block fully compensates for most of the difficulties of management and the saving in cost is a useful one. Advantages and disadvantages are, however, nicely balanced, and the choice is an open one depending on the individual grower's circumstances or preference. For early crops the use of soil blocks has disadvantages. (See under Potting, p. 20).

Propagation Temperature

The effect of temperature on growth and development has been the object of research in a number of countries. In this country the temperature referred to is always the accurately measured air temperature, but the thermometers used by many growers, even though accurate in themselves, may not indicate air temperature at all accurately. For example, in bright sunshine positive errors up to 20°F are possible, while at night smaller

negative errors can occur. When properly used the whirling thermometer provides the simplest accurate means of measuring air temperature.

Although the picture in not yet complete, it has been established that particularly large differences in plant response can result from differing temperature levels occurring during the propagating period. It has been shown, for example, that the most satisfactory temperature for the rate of growth is higher than that for the production of trusses with large numbers of flowers. Thus it is possible for a plant grown at high temperatures to produce ripe fruit on two small trusses when a low temperature plant still has only green fruit on its large bottom truss. Also the optimum temperature for satisfactory growth and development of the plant as a whole differs according to the prevailing supply of light. When the days are short and the weather dull the optimum may be lower, as with less light the rate of carbon assimilation within the plant is insufficient satisfactorily to support a rapid rate of growth. It is not practicable to state in precise terms what the temperature should be for all stages of propagation, as the optimum level may differ with time of year, weather, locality, suitability of propagating house and the variety. However, while adjustments of temperature for any particular batch of plants must be left to the skill and judgment of the grower, consideration of the following findings of recent research will help in making his decision.

High temperatures during germination increase the number of rogue plants (see p. 25) and a temperature of 65°F during the period from sowing to pricking out is likely to prove more satisfactory than the 70°F commonly applied. Once the seed leaves have opened out, high temperatures increase the growth rate but reduce the number of flowers formed on the bottom truss. On the other hand, if lower temperatures are used with the object of obtaining a large bottom truss, they may unduly retard growth and delay the first pick. Whereas the effect of high temperatures is to increase growth rate but reduce the number of flowers in the first truss, the effect of extra light is to increase both these factors and the fundamental importance of a well-lit propagating house cannot be too strongly emphasized.

Temperature affects not only the number and earliness of fruits but also their shape, and unduly low temperatures may result in an increased proportion of misshapen multilocular fruit, especially on naturally large fruited varieties.

To meet the varying needs of different aspects of plant development, some compromise over temperature is essential. Many growers of early tomatoes sow in October or November and it is thought that until mid-January night temperatures of 56–60°F, depending on the weather, will normally give satisfactory results. An experienced grower will judge by studying the appearance of his plants what further adjustment may be needed.

For these early-sown plants, some form of root restriction is essential to promote a proper development of the flowers, and the higher the air temperature the more important this is.

It has been shown that from mid-January onwards higher night temperatures are advantageous provided the amount of light reaching the plants is adequate. The improvements which have been observed are increased weight of early fruit and better grading for shape. It appears that, with an average day temperature (sunrise to sunset) of 68°F, a satisfactory night

temperature during this stage of propagation is about 62°F. No research has been made to find the effect of daytime temperature during propagation on the subsequent yield and quality of fruit, but current practice is to allow the temperature to rise with sun heat, with ventilation starting at 65–70°F. When the plants are illuminated by means of mercury vapour lamps (see next section) it is most important to ensure that the general air temperature of the house is kept at 60°F. Lower temperatures than this may check growth, higher may endanger the development of the first inflorescence, i.e., either deviation may diminish or even nullify the potential benefits of correct illumination. There is little doubt that the failure to achieve a satisfactory temperature balance in the propagating house is responsible for many of the unsatisfactory results experienced in the use of artificial illumination.

Artificial Illumination

Research has indicated that the use of artificial light during propagation can be advantageous. The type of lamp recommended for seedling illumination is the 400 watt high-pressure mercury-vapour lamp, mounted in a special reflector with a choke and capacitor for operating it. The MBFR/U fluorescent mercury-vapour lamp with built-in reflector is a suitable alternative. In the propagating house the lamps are suspended at a suitable height and spacing over the bench, and the proprietary type of lamp used for the purpose illuminates an area approximately $4 \times 3\frac{1}{2}$ ft, the mean light beneath a row of lamps being about 430 foot-candles when suspended $2\frac{1}{2}$ ft above the tops of the seedlings. The most economical use of the light is made by packing the pots or soil blocks thickly under the lamps immediately after pricking out. The number under each lamp depends on the size of pot or block and the time it is intended to illuminate the plants, but for a 3–4 week period one lamp will treat about 150 plants in $3\frac{1}{2}$ in. pots or large blocks. After that there is danger of overcrowding. Illumination can usually be discontinued after 3 weeks when the plants should be moved to a naturally well lighted position and grown on in the usual way. More seedlings can then be pricked out to take the place of the treated plants, so that up to three lots of plants can be illuminated each winter.

House temperatures should be reduced after plants are removed from artificial illumination, the degree of reduction depending on circumstances. If the plants are to be grown on in an east-west house with good natural illumination then fairly high temperatures may be maintained, but if they are closely spaced in a north-south house with poor natural light after they have been under lamps, then the temperature should be lowered to 52–59°F, according to weather, to make sure that the plants do not run away.

The Fully Automatic Fixed Lamp System

This method is designed to give the maximum amount of illumination per day and the lamps are permanently fixed at about 4 ft apart above the centre line of the benches. The lamps are switched off by an automatic switch for 7 hours during the night, and on large installations by a photo-electric cell during periods of high natural light intensity during the day. On small installations the cost of the photo-cell is high in relation to the saving in electricity which would result, and in these cases the lights are switched off manually during sunny periods.

Movable Lamp Systems

A number of methods are used employing movable lamps where it is desired to spread the cost of the equipment over a greater number of plants than is possible with the fixed lamp system. A further advantage is that there will be a considerable saving in running costs where electricity is charged on a maximum demand basis. Where light is the limiting factor the rate of growth will be slower than with the fixed lamp system, as 12 hours of artificial light is the maximum which can be given with the movable lamp. In all cases the plants are divided into two batches which receive artificial light in turn. The lights are turned off manually during sunny periods. Where the aim is to use the equipment to the full, the lamps have to be moved late at night and the two batches of plants screened from each other to ensure that all plants get seven hours of darkness. The lamps can be moved in groups down the length of the bench as well as from bench to bench across the width of the house. The latter is often the most suitable method as it simplifies the mounting of the control equipment.

It has been found that 11 a.m. and 11 p.m. are usually the most convenient times for moving the lamps but even then the move at night is often inconvenient. Because of this and the difficulty of providing a light-proof screen between the two batches many growers prefer other systems. One which is commonly employed illuminates two batches of plants for a period of 8½ hours in every 24 hours, with a common off-period of 7 hours during the night. The lights are moved at noon, batch A receives artificial light from then up to 8.30 p.m., when the lights are turned off by a time switch until 3.30 a.m. the following morning. Batch A then receives more artificial light from 3.30 a.m. until noon, when the lights are moved to batch B and the process is repeated. As light screening between batches of plants is not necessary with this system, the control gear can be permanently fixed and the lamps moved to illuminate adjacent batches on the same bench or batches on adjacent benches. Heat equivalent to the electrical loading is produced by all lamps and care should be taken to see that the temperature under the lamps at plant level is maintained at the correct value. It is usual to illuminate each batch of tomato plants for about 3 weeks. Many factors affect the total cost of artificial illumination but as a general guide it can be estimated at about 2*d.* per plant. A detailed costing should be done for the particular conditions when artificial illumination is being considered seriously.

Careful planning of the cropping is necessary when lamps are used. For instance, in areas where winter light is poor it is of little use to raise plants very early under the lamps and then plant them out in poor natural light; the normally grown crop may catch up with the illuminated plants and there may be little difference in the time of picking. In such areas the best use can be made of the lamps by sowing later than usual and thus shortening the propagation period, with consequent saving in labour and fuel.

The final product of the propagating stage bears a direct relationship to the crop that is to follow. The plants should be sturdy, dark green in colour, with an abundance of white roots in the pots. Growers should not be satisfied with plants that do not fulfil these conditions and should spare no effort to discover the reasons for their failure to attain them. A good guide to the health of the plant is the appearance of the seed-leaves. These should

remain green and turgid until the plant has gone into its final quarters. Attention has already been drawn to the importance of the correct temperature during propagation and disappointing results are often due to ignoring the effect of the heat of the lamps.

Rogue Plants

Many varieties of tomato tend to produce some plants which show abnormalities and these are variously known as rogues, jacks, Christmas trees or feather-legs. They differ from normal plants by having very short internodes and smaller leaves with fewer segments. The tendency for side-shoots to develop early gives a feathery appearance and, most important of all, the first truss gives sterile flowers and later trusses yield only a few small fruits. Rogues should not be planted but culled and discarded as soon as they are detected.

When the plants have made five or six leaves recognition is easy but, by that stage, time and space have been wasted on the care of worthless plants. With practice recognition is possible when the first true leaf appears. At this stage a normal seedling has one well-developed leaf with a large terminal lobe and two or three very small segments near the stalk. A rogue of the same age will have two equally developed leaves each with three lobes about equal in size.

It is important to note that the production of rogues can be minimized. At the John Innes Institute 23 of 35 varieties grown in trials produced rogue plants, the average over a 7-year period ranging from less than 1 up to 18 per cent. It was found that temperatures during the time from sowing until the cotyledons open out affected the number of rogues produced; the lower the germination temperature, the lower the percentage of rogues. It was also found that the percentage of rogues produced and the position on the plant of the fruit truss from which the seed is taken are correlated, the first and second trusses giving a lower percentage of rogues than the third and fourth (see also p. 22).

When to Plant

The timing of sowing and planting for the earlier crops depends on climatic conditions and locality. The early sowings (mid-November) and plantings (late January–early February) should only be considered in areas of good winter sunlight, such as the southern coastal districts. In all cases when considering the practicability of very early sowing one should weigh the cost of heating, lighting, etc., against higher prices for early and total crop. It is also futile to produce well grown plants and then to set them in borders too early in the year when natural light is still poor.

Seedlings from sowings later in the year develop under much better conditions of light and temperature. The period from sowing to planting is usually reduced and good quality plants should be readily obtained.

The importance of planting at the right stage of growth is well recognized; for maincrops, planted in early or mid-March onwards, most growers consider this to be when the first truss is just showing. For earlier plantings and especially where spring light is not of the best a more developed plant is sometimes preferred, the plants being fed in the pots if necessary to avoid starvation. If the plants are not ready, planting may well be delayed beyond the planned date, but to delay planting because the borders are not ready

may lead to overcrowding and the production of drawn, spindly, pot-bound plants, resulting in a check to growth and corresponding loss of earliness and total yield. If in such circumstances sufficient room cannot be given on the stages, it is better to stand the plants out in some of the houses until the borders are ready for planting (see Plate V).

Well grown plants transferred from pots to cold, wet soils are liable to checks and the weakened roots are readily invaded by bacteria and fungi which would not attack healthy roots growing in a suitable environment. Plants with damaged roots will not produce a full crop.

Facilities for Good Propagation

The best results cannot be obtained if the available equipment is out of date or in a bad state of repair. Where possible it is best to have a properly laid out compost shed, with storage bins and sterilizing plant, close to the houses to be used for propagation and connected to them by concrete floors or paths to minimize the risk of disease infection. For large-scale work a soil shredding machine is desirable and, although all this involves capital outlay, the ultimate saving in labour costs and the increased efficiency of operation and production may fully justify the expense. (See Bulletin No. 22: *Soil Sterilization.*)*

SOIL MANAGEMENT AND MANURING

Preparation of the Soil

In houses where tomatoes are grown each year and cropped until the autumn, preparation will begin with the removal of the haulm and roots of the previous tomato crop. It is essential that as much as possible of the old root systems should be removed during this operation as they may be carrying infective organisms, including tomato mosaic virus. Together with the old haulms such roots should be burnt, or failing this taken to a site well removed from the glasshouses. If the haulm is composted the product should on no account be used subsequently in the glasshouses or on open land adjacent to them. When lifting, the opportunity should be taken to examine some of the roots closely for the cysts of potato root eelworm attached to them and for the galls caused by root knot eelworms (see p. 83).

When the remains of the previous crop have been cleared the framework and glass of the houses should be cleansed as described on p. 89.

Single digging, double digging (bastard trenching) and rotavation are methods commonly employed for soil preparation. Double digging is the most effective but the most costly. It enables bulky organic soil improvers, such as strawy manure, chopped straw, compost or peat, to be evenly incorporated in the bottom and top spits. In this way shallow soils may be deepened gradually and impervious or otherwise undesirable subsoils improved, thus encouraging a large and deeply ramifying root system. The addition of bulky organic materials to the maximum depth possible also increases soil aeration and drainage. This is of particular importance on heavy soils and where watering by hose pipe is practised. Experience suggests that double digging should be carried out every second or third season even on fertile soils, with rotavation or single spit digging in the alternate years.

* See Appendix III.

Rotavation offers a convenient method of incorporating bulky organic material. The cost is relatively low where the strips of soil within the houses are sufficiently free from such obstructions as side ties and heating pipes, but the effective depth of cultivation is not more than about 10 in. On some types of soil, rotavation may result in an undesirable pulverization and an over-fine tilth, causing damage to soil structure particularly if the soil is dry. On the other hand it is unwise to rotavate when the soil is wet, particularly if it is heavy. Rotavation practised continually over a period of years may also lead to the formation of a pan at about the depth to which the blades or tines of the equipment penetrate. An occasional double digging will ensure that this does not occur.

Soil Sterilization

Soil sterilization is a means of destroying pests and diseases in the soil. There are now very few growers who would question the need for the annual sterilization of glasshouse soils where successive crops of tomatoes are grown. The method to be adopted is a more controversial matter, however, ranging from partial sterilization by means of heat, usually applied in the form of steam, to the use of one or more of the chemical sterilants.

The choice of method should be decided in the light of individual circumstances. Where the glasshouses and the site are well suited for tomato growing and provide scope for long season cropping, under skilled management the yield potential will be high and annual sterilization by steam, although generally the most costly method, will probably be justified and lead to higher profits. In other circumstances, and especially where the crop potential is less or where steam cannot be made available, alternative treatments must be used. These include the use of chloropicrin, formaldehyde, metham sodium, phenolic fluids or DD. Detailed descriptions of these treatments and of soil sterilization by steam are given in Bulletin No. 22 and Advisory Leaflet 319: *Soil Sterilization.**

Organic Matter and Soil Conditioning

For the production of heavy crops of high quality fruit the plants must be able to develop and maintain large, healthy root systems with the fibrous feeding roots functioning efficiently throughout the season. Fibrous roots are particularly liable to damage when the physical condition of the soil is poor and when panning of the soil surface and impairment of soil structure occur. This is especially liable to happen on soils with high silt or fine sand fractions and watered by hose pipe.

A sufficiency of organic matter in the soil and its constant renewal in suitable form is an important means of improving the crumb structure of soil and of making it more stable. The minimum satisfactory level of organic matter for tomato crops is usually about 4 per cent, but it is difficult to lay down a precise requirement as much depends on the age of the organic matter and the type of soil.

In glasshouses both soil and air are warmer and the soil more uniformly moist than in the open, and decomposition of organic matter is therefore more rapid. The maximum benefit to the soil is obtained by the use of relatively undecomposed material, but on very light soils the use of fully

* See Appendix III.

composted bulky organics may be best. On heavier soils straw, strawy manure or other coarse materials, such as coarse peat, usually give the most satisfactory results.

Horse Manure

Horse manure is now scarce and more costly than in the past, but many growers consider it worth while to pay substantial prices for what they believe to be the most satisfactory bulky organic manure for the tomato crop. As purchased it is not a uniform product, varying in the proportion of straw to droppings, the state of decomposition, according to how long it has lain in heaps or stacks, and in the amount of water present.

If the sample contains plenty of droppings or is already well decomposed, additional clean straw, preferably wheat, can be added either in the glasshouse during digging in or as it is stacked in readiness for use. Some growers partially compost it, adding straw before doing so. This is a method often practised on lighter soils. Much of the horse manure now obtainable is from racing stables and contains a good deal of straw so that it is very suitable for tomato growing. In addition to supplying organic matter in bulk, horse manure applied at normal rates will provide appreciable quantities of the major plant nutrients and an average sample may be reckoned to provide, in each ton of manure, about 12 lb nitrogen as N, 5 lb phosphate as P_2O_5 and 10 lb potash as K_2O. Other essential nutrients such as magnesium and manganese are also present.

When the straw content of the manure is high, especially if it is not saturated with urine and has not been partially composted, the initial effect in the soil for the first few weeks may be to lessen the available supply of nitrate nitrogen to the crop. This denitrification is the result of the activity of soil organisms which attack and decompose the manure. The effect upon the plant depends on the amount of available nitrogen already in the soil and in some circumstances temporary denitrification may be an advantage. In this connection experience shows that, if the supply of nitrogen is relatively low during the early weeks of the growing season, a balanced plant with a high proportion of root to top and with good truss and flower development is more likely to be produced. Hence some lowering of the supply of available nitrogen at this time may be advantageous and any insufficiency can quickly be corrected by liquid feeding or top dressing. Later in the spring nitrogen will be released by the progressive decomposition of the strawy manure and by this time the plant will be requiring an increased supply.

The quantity of stable manure which should be applied depends upon the circumstances. An average of 30–35 tons per acre per annum is commonly used and seems to maintain the organic matter reserves in glasshouse soils. When a soil is frequently steam sterilized, organic matter decomposes more rapidly and in such circumstances the higher rate of application would be needed. On impoverished or difficult soils, dressings of up to 60 tons per acre may be given with advantage until the required improvement in organic matter and soil condition has been effected.

Peat

Peat is frequently used and the rate of application will depend upon whether it is being applied as a complete alternative or as a supplement to horse manure. In the former case dressings of up to 10–12 tons per acre

have proved satisfactory. The coarse granulated types are usually chosen and should be free from dust. Satisfactory samples have a pH of about 4·5. Peat is very retentive of moisture and for this reason its effect on clay soils may not be so good as that of straw or stable manure. In large quantities it is apt to make the land spongy.

Straw

As a bulky organic manure wheat straw is usually preferred because it maintains its form and structure for a longer period than oat or barley straw.

When straw forms the only source of organic matter, the rate of application in preparation for a tomato crop is usually from 6–8 tons dry straw per acre. It may be incorporated in the course of double digging or can be rotavated into the soil. In the latter case many growers prefer to shorten the straw by cutting the bales into convenient lengths. When digging in, the best results are obtained by spreading the cut straw evenly in the trenches, care being taken to avoid laying it horizontally as this leads to puffiness and difficulties in watering. On sloping land straw walls inserted at suitable intervals across the slope help to intercept water applied by hose and so ensure uniform absorption. Such walls may be placed as digging proceeds or inserted into V-shaped slits made with a spade if the initial cultivation has been by rotavation or single spit digging.

Where straw is used in appreciable quantities, the denitrifying effects may be such that the plants will suffer from nitrogen starvation unless dressings of nitrogenous fertilizers are given to counteract the effects of decomposition. On steamed soils 1 cwt hoof-and-horn or ammonium nitrate-lime mixtures may be given per ton of straw. In other cases, and especially where the inherent fertility of the soil is known to be low, 1½–2 cwt of these fertilizers per ton of straw may be given.

Other Materials

Cow and pig manure, although more readily available than stable manure, are disliked by most experienced tomato growers as growth following their use is often excessively leafy. Although additional straw could be used to counteract this effect, soil condition does not always show the same degree of improvement. Manure from swill-fed pigs may also introduce disease.

On silts and other soils of fine particle size prone to surface panning the addition of peat and grit to the soil, in proportions approximating to a John Innes Compost, is occasionally practised. To each estimated 7 cu. yd of soil, 3 of peat and 2 of grit are added. Because of the high cost it is usual to add the peat and grit only to the strips of soil which the tomato plants will occupy, i.e., to slits or shallow trenches 24 in. or so in width. Any soil displaced from the strips is placed on the pathways which are then trodden firm.

Re-soiling

It is the practice on some nurseries to replace the top 12–18 in. of soil every 3 or 4 years with the twofold object of avoiding the need for steam sterilization and ensuring good tilth and structure. The improvement is often short-lived because of the rapid re-contamination of the new top soil from deep-seated organisms, such as the verticillium wilt fungus, which may

be present in the subsoil, and to the frequent use of top soil from cultivated land containing too little grass root fibre. When re-soiling is to be undertaken top spit from good quality ley should be used. If suitable soil is unobtainable some of the outdoor land on the nursery could be sown to leys, selecting grasses suitable for this purpose such as New Zealand H_1 hybrid ryegrass or S22 perennial ryegrass.

When soil changing can be planned ahead it is best to take samples for analysis from the open land a year or more in advance, so that any fertilizers shown to be necessary may be applied in good time. This may have the added advantage of improving the growth of the grass ley and thereby the physical condition of the soil.

The National Agricultural Advisory Service should be asked to advise on the manurial requirements of any land intended for re-soiling and an examination for pests such as wireworm and potato root eelworm should also be made. If potato root eelworm is found the soil must not be used.

Winter Flooding

Winter flooding is the term commonly used for the application of substantial quantities of water to a glasshouse soil at some time prior to the planting of the new season's crop. Its purpose is twofold: to replenish the reserves of soil moisture in readiness for the new crop and to wash out residual salts or other substances left from past manuring or cropping should these be known or thought to be present in amounts likely to be harmful.

The amount of water required to bring the soil to field capacity (i.e., the amount required to re-moisten the soil fully but without any free water running to drainage) to any given depth depends on the extent to which the soil has been permitted to dry out and on the soil type. On a clay soil the water holding capacity was found to be 58 per cent, whereas on a sandy soil the figure was 26 per cent. The soil moisture deficit represents the difference, if any, between the amount of water lost by transpiration and evaporation during the later life of the previous crop on the one hand and the amount applied on the other. Where watering of the previous crop was continued until just prior to clearance, the amount of water required in order to make good the deficit will be quite small, perhaps 22,000–44,000 gal per acre, this amount being roughly equivalent to 1–2 in. of rain. Where, however, the watering of the previous crop was neglected in the later stages of growth, from 45,000–70,000 gal per acre may be found necessary.

In any event it is advisable to apply the water over a period of time, about 22,000 gal per acre at each application. Between applications the depth of penetration can readily be checked with the aid of a soil auger. Borings should be made at a number of points, using an auger $3\frac{1}{2}$ ft in length. It is helpful to make a few trial borings before watering commences and then to assess the moisture status of the soil and subsoil.

The present tendency is to apply smaller quantities of water than hitherto, as the application of excessive quantities leaches useful nutrients into the drains and damages the structure of the soil.

The circumstances in which additional applications of water should be given for the purpose of washing out chemical residues or excessive concentrations of nutrients which will have accumulated as a result of past manurial practice is a more difficult decision for the grower to make. The quantities

which should be applied are also a matter to be decided in the light of individual circumstances. The soil type, depth of the natural water table and nature of the excess chemical salt or other harmful substance will need to be considered and the County Horticultural Advisory Officer should be consulted.

The method of applying winter flooding should be given careful consideration. Where irrigation lines can be used, they achieve more effective and even penetration of water and cause less damage to soil structure than where water is applied by hose. Irrigation usually leaves the soil in a more friable and workable condition and it can therefore be made suitable for planting much sooner than under the conditions created by hose flooding (see Plate IV).

Spray lines for this work are usually of 1 in. bore, but may be of larger diameter according to the length of the glasshouse to be dealt with. They are best fitted with nozzles giving a mist-type spray and so spaced on the line as to provide even distribution. With nozzles which give a larger droplet it is best to use oscillating lines or to take other measures to avoid excessive precipitation which may cause water-logging and surface panning. With either spray lines or hoses it is advisable to restrict applications at any one time and to move the equipment round the houses to allow a day or two for downward penetration before the next application commences, making borings with the soil auger to check penetration meantime.

When the soil has been steam sterilized or quantities of dry straw have been used, the bulk of the winter water should be applied after these operations but before the application of any base fertilizer. The work of cultivating in such fertilizers will help to counteract undue soil packing caused by winter flooding.

Nutrition

The main nutrients required by the tomato are potassium, nitrogen, phosphorus, magnesium and calcium. These are supplied partly by dung and partly by fertilizers added in the base and top dressings or by liquid feeding. The total quantity of nutrients removed by a tomato crop of 50–80 tons per acre is about 800–1300 lb potassium (as K_2O), 400–600 lb nitrogen (as N), 70–150 lb phosphorus (as P_2O_5), 110–170 lb magnesium (as MgO) and 500–800 lb calcium (as CaO). The tomato plant has a very high uptake of potassium and nitrogen, a moderate uptake of magnesium and a low uptake of phosphorus. In addition to removal by the crop, nutrients are also lost in drainage water. Even with careful watering and reducing drainage to a minimum, 20 per cent of the nitrogen and 12–15 per cent of the potassium applied during the growing period is lost in drainage. This loss increases as water application rises in excess of requirements. If nutrients are applied in excess, potassium and phosphorus accumulate in the soil and, if build-up continues over a period, it may give rise to a high salt concentration in the soil. The aim of a good manurial programme should be to provide for plant uptake and losses without giving any progressive build-up of reserves in the soil once an adequate level has been reached. Soil analysis is helpful as a guide to the preparation of a manurial programme. It should always be done on a new nursery and used as a periodic check on established nurseries. Advice on manuring and, where necessary, a soil analysis can be obtained by consulting the County Horticultural Advisory Officer.

In the past dung was invariably used as the main source of bulky organic matter but it is now being replaced by peat on many holdings. Dung is of variable composition and, in addition to organic matter, it supplies considerable quantities of nutrients. A 40 ton dressing of dung applies about 500 lb nitrogen, 400 lb potash (as K_2O) and 200 lb phosphate (as P_2O_5) per acre, allowance for which must be made in the manurial programme. On the other hand, peat is a much more standard material containing little available nutrients.

Uptake of nutrients by the tomato plant is slow in the early stages, increases to a peak in June and July and then declines to the end of the season. The maximum uptake of potassium takes place from the end of May to the end of July. Phosphorus follows a similar pattern but has a much lower peak. For nitrogen, calcium and magnesium the maximum uptake occurs between mid-June and mid-July. Potassium and nitrogen requirements depend on the rate of growth but nitrogen needs to be more closely related to light conditions.

Nitrogen is necessary to maintain growth and give high yields but it must at all times be properly balanced with potassium. If nitrogen is not balanced with a high potassium supply, excessive vigour may result in the early period of growth and setting of the fruit may prove difficult. The problem is most acute on steamed soil and is best solved by a combination of a high potassium level and strict water control. Where nitrogen is high in relation to potassium, fruit quality and uniformity of ripening are invariably poor. A high potassium level increases fruit acidity, improves flavour and decreases the amount of non-uniformly coloured fruit.

If the potassium level is high the ability of the tomato plant to take up magnesium is reduced and magnesium deficiency symptoms frequently result. The evidence from recent work on this deficiency suggests that yield is unlikely to be reduced except where the symptoms appear early, as in hot sunny seasons. Magnesium uptake is satisfactory when the soil magnesium:potassium ratio ($MgO:K_2O$) is about 1:1. On many glasshouse soils the ratio is of the order of 1:10 and this imbalance can only be redressed by heavy applications of magnesium salts. Once the imbalance has been corrected it is only necessary to make good the loss through uptake and drainage each year. More magnesium than phosphorus is removed from the soil by the tomato plant and magnesium should be considered as a major nutrient requirement.

Calcium uptake is fairly constant throughout the season. The crop requirement is normally met by the natural reserves of calcium in the soil or by the routine liming of soils in which calcium is low. No other provision is usually needed.

Liming

Liming of glasshouse soils should only be done when a need is shown by soil analysis. The tomato does best when the soil reaction is slightly acid, in the range pH 6·0–6·5. Above pH 6·5 liming is not necessary or desirable and above pH 6·8 yield is depressed and the availability of phosphates and some minor elements is decreased. The tomato plant is tolerant of a fairly wide range of soil acidity and alkalinity and it may be necessary to take account of other crops, such as lettuce, which have a narrower range of tolerance and which may be grown in the same glasshouses.

The main forms of lime used are ground chalk, ground limestone and hydrated lime. Hydrated lime is somewhat caustic and unless a quick reaction is needed ground chalk or limestone is preferred. Whatever the material used it should be finely ground and intimately mixed with the soil by hand or mechanical cultivation. Magnesian limestone can be used where the magnesium status requires building up, but it should not be applied where the soil is already neutral or alkaline and shows no lime requirement.

Fertilizer Application

Base Dressings

Base dressings are very important in supplying the nutrient needs in the early stages of growth and in establishing and maintaining a satisfactory salt concentration in the soil. Salt concentration can be of great help in producing a controlled plant, the flowers of which will set more readily and produce good quality fruit in the early part of the season. Soil salinity markedly affects growth, yield and fruit quality. Growth is restricted and yield reduced at pC values below 2·7, whereas at pC values over 3·0 growth control is poor, plants soft and vigorous and fruit quality indifferent. The aim should be to produce a pC value of about 2·9 (=Cf 12) by the application of potassium and magnesium in the base dressing before planting.

Nitrogen. Great caution should be exercised in applying nitrogen in the base dressing, particularly where dung has been added or where the soil has been steamed or treated with metham-sodium, chloropicrin or DD mixture. The nitrogen released by these treatments is frequently sufficient for early growth of the crop but much depends on the soil, frequency of sterilizing and level of fertility. Hoof-and-horn is the fertilizer most commonly used to supply nitrogen in the base. On poor soils with a late planted crop, under good light conditions the rate of application may be up to 10 cwt per acre. For average conditions on unsteamed soil 6 cwt is recommended. On steamed soils nitrogen should normally be omitted or restricted to a maximum of 3 cwt. The nitrification of organic fertilizers such as hoof-and-horn proceeds much more rapidly in glasshouse soils than formerly believed and this is a further reason for exercising strict care in their use.

Phosphorus. Except in the propagating stage the tomato requires much less phosphorus than nitrogen and potassium. Past practice has been to use fertilizer mixtures with a high phosphate content and this, coupled with the use of heavy dressings of dung, has produced an unnecessary accumulation of phosphate in most older glasshouse soils. Where reserves are high phosphate may be omitted altogether. On most nurseries 3 cwt per acre superphosphate is adequate, increasing to 6–8 cwt if the phosphate status is low. Triple superphosphate can be substituted on an equivalent phosphorus basis and does not add gypsum to the soil as does ordinary superphosphate.

Potassium. Potassium applied in base dressings supplies nutrient needs and also increases the soil salinity, thus acting as a growth controller. Sulphate of potash is invariably used, 6–10 cwt per acre being adequate on most soils. The quantity should be assessed in each case on soil analysis results. On new soils it may be necessary to increase the quantity up to 40 cwt worked into the top 12 in.

Magnesium. Where potassium is high the soil magnesium : potash ratio can only be corrected by relatively heavy dressings of Epsom salts, Kieserite or, where there is a lime requirement, magnesian limestone. Before heavy dressings of magnesium are applied the advice of the County Horticultural Advisory Officer should be sought. Epsom salts may be needed at the rate of 40–50 cwt per acre. At this rate of application it will have an effect on soil salinity, but this is only about half that of an equal weight of sulphate of potash. Where it is undesirable to build up soil salinity half the Epsom salts should be replaced by Kieserite.

It is best to concentrate first on getting the right potash level, as magnesium deficiency can usually be controlled easily by spraying. The standard solution recommended is 2 lb Epsom salts in 10 gal water, but at this strength there is some risk of leaf scorching. Damage rarely occurs when the strength is reduced to 1 lb in 10 gal with the addition of a suitable spreader. Risk of scorch is least when the leaves are just wetted with a fine spray and the deposit dries rapidly.

Base dressings can be mixed by the grower from straight fertilizers or each material applied separately. Alternatively, they can be purchased as proprietary mixtures, but the grower should ensure that the correct amount of each component is applied and that the mixture is not overloaded with phosphate or unnecessary filler. The fertilizers should be applied evenly over the soil surface after winter flooding and when the soil is in a workable condition. They should be worked into the top 9 in. of soil not less than 7 days before planting. Dressings of lime should be applied separately and worked in before the fertilizer application, preferably before flooding.

Top Dressing and Feeding

To maintain satisfactory growth and cropping, the plants must be regularly fed with suitably balanced fertilizers applied dry or in solution. The main need of the tomato plant is for potash and nitrogen, the balance between the two being governed by the vigour of the crop, stage of development and seasonal variations in uptake. If phosphate has been applied in the base dressing, it is unnecessary and wasteful to apply it in top dressings or liquid feeds unless soil analysis shows a clear need.

Until recently the most popular method of feeding was to apply soluble or readily available fertilizers to the soil surface between the plants immediately before watering. The application of water then carried the nutrients down to the roots in amounts varying with the solubility of the fertilizer mixture and the quantity of water applied. This method is rapidly being replaced by the application of nutrients in solution through a hose pipe or through fixed pipe irrigation systems, the concentrate being injected into the main water flow by a proportionating device (see p. 72). Liquid feeding saves labour, gives a more efficient use of fertilizers, more rapid availability of nutrients, more even distribution in the soil, better control of growth and no accumulation of undesirable residues.

Solid Feeding

In the past solid feeds have been applied according to the judgment of the grower and his assessment of the needs of the crop. With the demand for greater precision there is a need to adopt a more rational basis for calculating fertilizer requirements. Table 1 shows the nitrogen and

potash requirements, as sulphate of potash and urea equivalents, allowing for plant uptake and likely losses in drainage.

TABLE I

Nitrogen and potash requirements

	Yield (ton/acre)			
	50	60	70	80
Potash (cwt sulphate)	16	21	25	29
Nitrogen (cwt urea)	8	12	14	16

Knowing the likely yield, after allowing for variety, time of planting and length of season, an estimate of total requirement can be obtained by using the above table. The figure obtained should then be reduced by the sulphate of potash and urea equivalent of any potash and nitrogen applied in the base dressing. If dung was applied, a further deduction of 1 cwt sulphate of potash and $1\frac{1}{4}$ cwt urea per 10 tons dung should be made. The resulting figure will give the amount of potash and nitrogen to be applied as sulphate of potash and urea or the equivalent in top dressings.

The most suitable potash fertilizers for glasshouse tomatoes are sulphate and nitrate of potash. Mixtures containing muriate should not be used under glass because of the danger of chloride residues. A wide range of nitrogenous fertilizers can be used including urea, sulphate of ammonia, ammonium nitrate-lime mixtures, hoof-and-horn meal, dried blood, fish meal and meat meal. The unit cost of nitrogen in the organics is about four times that in sulphate of ammonia or ammonium nitrate-lime mixtures, so that organics cannot be justified on economic grounds as they are not demonstrably superior to inorganic sources of nitrogen. When sulphate of ammonia is used, allowance must be made for the acidifying effect of this fertilizer on the soil.

Feeding should begin when the fruits on the first truss are set and swelling. If growth is vigorous the first feed may be straight sulphate of potash, otherwise a mixture with a K_2O:N ratio of about 2:1 should be fed until the end of May or early June for crops planted mid-February to early March, or until the fruits on the fourth truss are swelling for later plantings. In June and July the K_2O:N ratio may be changed to 1:1, returning to 2:1 in August. Feeding should finish about 4 weeks before pulling out or at the end of August, whichever is the earlier, after which only plain water should be given or withheld altogether if it is desired to dry out the soil. Fertilizers should be applied every 10 to 14 days, about one-eighth of the estimated need being applied in April, one-quarter in each of the three months of May, June and July and one-eighth in August. It is important not to exceed very greatly the estimated potash requirement and this is best checked by keeping a note of the cumulative total of potash applications. Greater liberties can be taken with nitrogen as this is not held by the soil but is quickly leached out.

A grower may make up his own mixtures or apply the components separately. Alternatively, he can purchase proprietary compounds making sure that the K_2O:N ratio is correct and avoiding those containing unneces-

sary phosphate. It is wise to check the cost of unit values of nitrogen and potash in proprietary mixtures to ensure that they are an economic purchase.

Liquid Feeding

Liquid feeding supplies nutrients in solution and in a form immediately available to the plant. A fertilizer concentrate is injected into the water applied to the soil by hose or irrigation system so as to give regular feeding at each watering. The most suitable materials for making up the concentrate are potassium nitrate (42% K_2O, 13% N), urea (45% N) or ammonium nitrate (35% N). Potassium nitrate is the only suitable source of potash and of the two other sources of nitrogen urea is usually preferred. Ammonium nitrate becomes wet if exposed to the air and so must be stored in airtight containers away from heat and naked flames. Contamination with oil, grease and organic materials must also be avoided. Urea is easier to store and pleasanter to handle and the nitrogen is only slightly less readily available than in ammonium nitrate. It should be of fertilizer quality with a biuret content not exceeding 1 per cent.

Concentrates

Concentrates should be made up in wooden, asbestos, concrete, earthenware or glazed containers. Iron or steel containers may also be used but they must not be galvanized and must be painted with bitumen on the inside to resist corrosion. The basic concentrate is made by dissolving potassium nitrate at the rate of 1½ lb to 1 gal water. It is easier to make up the solution if the potassium nitrate is placed in a bag of fine, loosely woven material which is suspended in the water overnight. It is not advisable to attempt to make a stronger concentrate as there is risk of recrystallization in cold weather.

Three stock solutions suffice for most purposes, with K_2O:N ratios of 3:1, 2:1 and 1:1, designated High Potash, Standard and High Nitrogen, respectively. The basic concentrate of potassium nitrate has a K_2O:N ratio of 3:1 and the other two can be prepared directly from it by adding ammonium nitrate or urea in the quantities shown in Table 2.

TABLE 2

Preparation of stock nutrient solutions

K_2O:N ratio	*Composition (oz/gal)*			*Nutrient content (lb/10 gal)*	
	Potassium nitrate	*Urea or*	*ammonium nitrate*	*K_2O*	*N*
3:1 High potash	24	—	—	6·3	2·0
2:1 Standard	24	5	6	6·3	3·3
1:1 High nitrogen	24	16	20	6·3	6·3

The potash content of each feed is the same and further nitrogen is added to give the standard and high nitrogen feeds. Where it is desired to give magnesium to replace plant uptake, Epsom salts should be added at the rate of 2 lb per 10 gal or 3 oz per gal. If it is necessary to colour the feed in order to check dilution disulphine blue, VN150, should be added at the rate of 1 oz per 10 gal. Caramel at 2 fl. oz per gal is a more expensive alternative. Where colour only is required in the concentrate the above quantities can be reduced considerably. For simplicity it is only necessary to maintain the basic concentrate, urea or ammonium nitrate being added when necessary and dissolved immediately before use.

Application

Generally, concentrates should be applied at a constant dilution of 1:200. Small amounts of high potash feed may be applied at a dilution of 1:80 if growth control is needed, but vigour is better controlled by restricting water than by using concentrated nutrient solutions. The standard feed should be used from the start of feeding until early June, followed by the high nitrogen feed in June and July, returning to the standard feed at the end of July or early August. Feeding should be linked to water application controlled by one of the methods described on p. 70 and should cease at the same time as for solid feeding (see p. 35)

This feeding programme will apply up to 900 lb N and 1,200 lb K_2O per acre over the season. The total amount of fertilizer required for this can amount to 27 cwt potassium nitrate and 10 cwt urea, or 12 cwt ammonium nitrate, costing about £150. Proprietary solid or liquid concentrates can be used as alternatives; they save the trouble of making up concentrates but are likely to be much more costly per unit of nutrient.

PLANTING

Winter flooding should be completed in good time so that excess water is drained away and the soil is evenly moist down to at least 30 in. with the surface slightly dried out. Surface cultivations and planting can then proceed without delay. Where houses have been prepared in early winter and a lettuce crop taken, watering should be sufficient only to restore the soil moisture deficit, since at this time of year planting will be urgent.

Soil Temperature

Before planting can safely take place, the minimum soil temperature should be 57°F at 6 in. depth. This should be checked with a soil thermometer at 9 a.m. for several days prior to planting.

Use of Pots and Containers on Borders

In some districts, particularly in the south and west of England and in Guernsey, it is common practice to set out plants in pots or other containers which are stood on the soil surface or sunk about 3 in. into the border so that the plants eventually root through into the border soil. This practice appears to be on the increase especially on nurseries with soil problems.

Concrete pots may be used but bitumenized fibreboard pots 9–10 in. diam. are now becoming popular for this purpose. In heated houses it is

usual to run the rows of pots lengthways (north and south) down the house on either side of the hot water pipes (see Fig. 1, p. 39). The soil in the containers is then easily warmed by direct radiation and favourable conditions are created for the development of fibrous roots, though large or taproot production is temporarily restricted. This ensures more balanced growth with good truss development and readier setting of fruit on the early trusses.

Sowings can be made in November and the seedlings handled in the normal way. It is not usual to sterilize the whole of the border if pots are to be set out as described above, the pathways between the lines being omitted, and to discourage rooting into the unsteamed strips these are often trodden firm and left unwatered. The pots should also be sterilized if they have been used previously and then filled with soil from the treated part of the border. The rows are so arranged that the plants stand about 18 in. apart on either side of the pipes.

After-treatment follows normal lines but, when the plants root into the border soil, less watering and feeding will be required than for plants in pots on hard surfaces. For very early crops, growing in short days with restricted light, some growers delay the rooting of the plants into the borders by placing tiles or squares of polythene beneath the pots or by moving the containers at intervals.

Most varieties respond to this treatment and crops grown in this way are earlier and of better quality than from plants in borders.

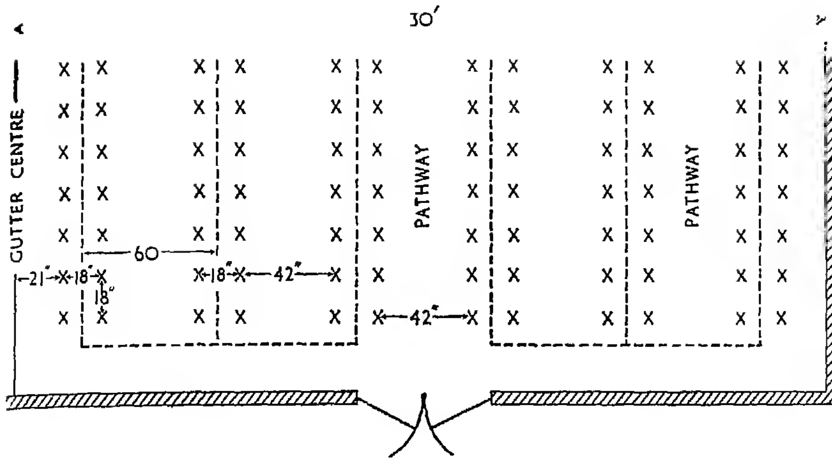
Spacing and Plant Arrangement

Experiments in recent years have shown that in heated tomato houses and with the variety Potentate the optimum yield of good sized, good quality fruit is obtained with a spacing of 14,500–17,500 plants per acre. Other factors, such as convenience of working in and picking the crop and likelihood of leaf mould, must also be considered in deciding the density of planting. The arrangement of plants is influenced by the position of permanent heating pipes and ideally these should be at about 5 ft centres across the house. In the light of all considerations it is probable that somewhere around 14,000 plants per acre will be most satisfactory (see Tables 3 and 4).

Plants may be arranged in two ways; with the plant rows lengthwise down the house or with the rows across the width of the house.

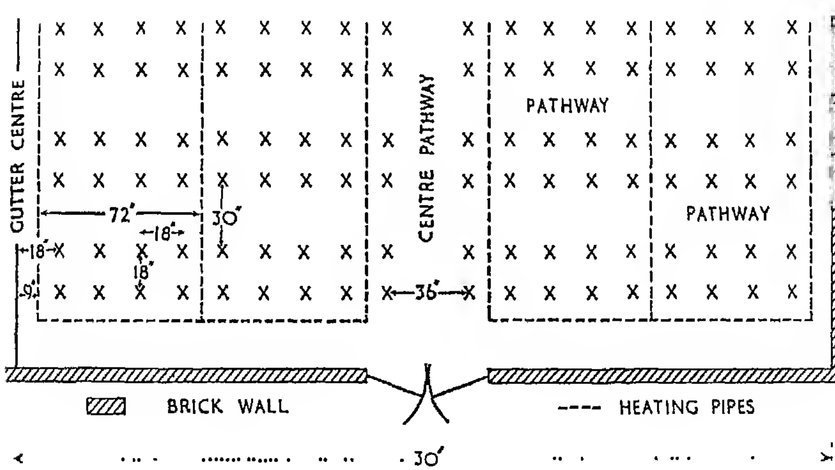
With houses 5 ft or more high at the gutters and the heating pipes fairly evenly distributed across the house at about 5 ft centres, the arrangement of the plants in pairs of rows running lengthwise down the house and about 9 in. on either side of the pipes, as shown in Fig. 1, has many advantages; congenial soil and local air temperatures are efficiently produced and air movement is assisted between the plants which are ideally placed for the archway method of training (see p. 49). Low level irrigation lines can be arranged within the rows or hose watering conveniently carried out from standpipes at approximately 50 ft intervals down the house. At these points a cross path may be provided to facilitate cultural operations and the transport of picked fruit.

The efficiency and cost of picking operations is influenced by spacing and plant arrangement. Consideration should be given at this stage to arrangements for provision of empty and removal of full containers from the house.



Long-row method of planting

FIG. 1



Short-row method of planting

FIG. 2

Where the pipes are awkwardly situated for lengthwise planting, a main pathway 36 or 42 in. wide may be provided down the centre of the house and the plants set out in pairs of short rows at right angles to it, as shown in Fig. 2.

Table 3

Numbers of plants per acre obtained by different row spacings
Long row planting as shown in Fig. 1

Distance between rows (in.)	*Distance within rows (in.)*	*Approximate no. of plants per acre**	*Area of ground per plant "in the crop" (see Fig. 1) (sq. in.)*
42 × 18	13	15,159	390
42 × 18	14	14,143	420
42 × 18	15	13,068	450

Table 4

Short row planting as shown in Fig. 2

Distance between rows (in.)	*Distance within rows (in.)*	*Approximate no. of plants per acre**	*Area of ground per plant "in the crop" (see Fig. 2) (sq. in.)*
27 × 18	18	13,591	405
27 × 18	16	15,100	360
30 × 18	16	14,229	384
30 × 18	15	15,652	360
36 × 18	15	12,472	405
36 × 18	12	14,723	324

* End paths have been allowed for but not cross paths or other unpredictable obstructions

Planting

The holes for the young plants are often taken out in advance of planting time with a solid plunger-type dibber or a planting tool which removes the required amount of soil. The planting tool does not compress the surrounding soil and is to be preferred, particularly in heavy soils.

On a small scale planting is often done with a trowel, the hole being made and the plant set in one operation. In all cases the holes should allow the ball of soil to fit snugly and, after gentle firming of the surrounding soil, the surface of the block or ball should be at or slightly below soil level.

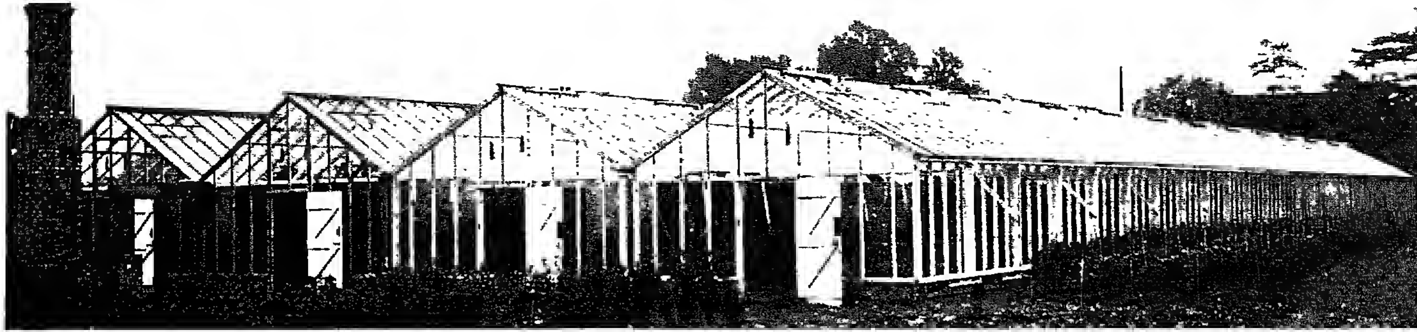
Prior to planting the rows are marked out with canes at each end, or with paint marks on the pipes or walls. A line marked at suitable intervals is stretched along the row enabling each plant to be set accurately in place. Two workers with two lines, working a section up one line and down the other, eliminates unnecessary walking.

Usually plants are stood in or near their stations immediately prior to planting, but if propagating space is urgently required they may be stood out for a few days before planting. Care must then be exercised to give adequate water without causing excessive wetting of the planting sites.

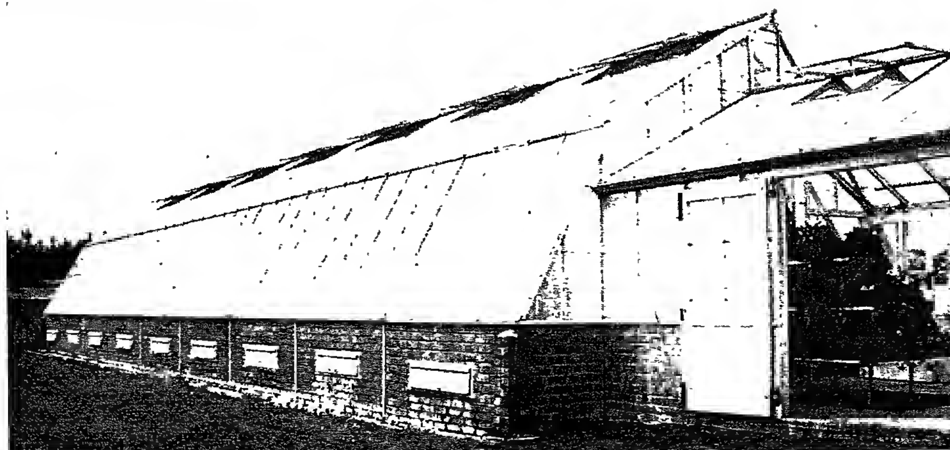
Immediately before planting the young plants should be given a good watering to ensure a moist ball and so reduce further watering. Probably one or two ball waterings will be needed before they are adequately rooted.

General view of a tomato nursery—vinery-type glasshouses *The Grower*

PLATE I



Aeroplane-type glasshouse for tomato growing

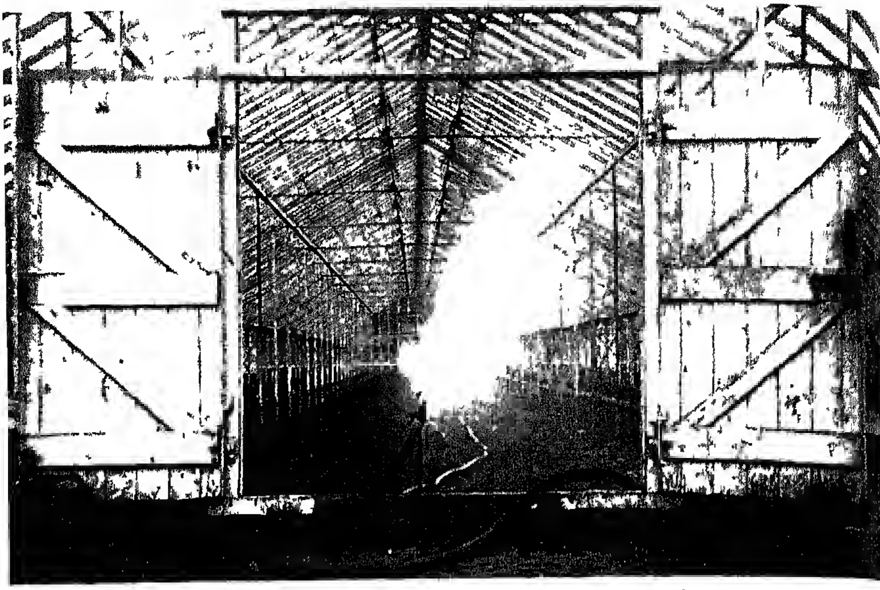


High eave east-west orientated propagating house for tomato raising

Tomatoes in Dutch light structures

Positioning of tomato rows in relation to heating pipes (small diameter steam pipes) to obtain full advantage of the heat

PLATE III

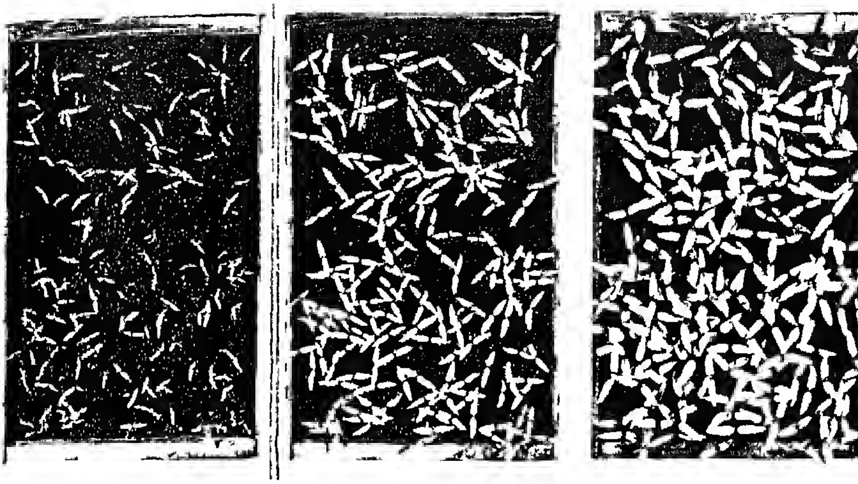


Winter flooding is done most effectively by spray line

National Institute of Agricultural Engineering

Trickle irrigation of tomatoes

PLATE IV



John Innes Horticultural Institution

Tomato propagation age of transplanting

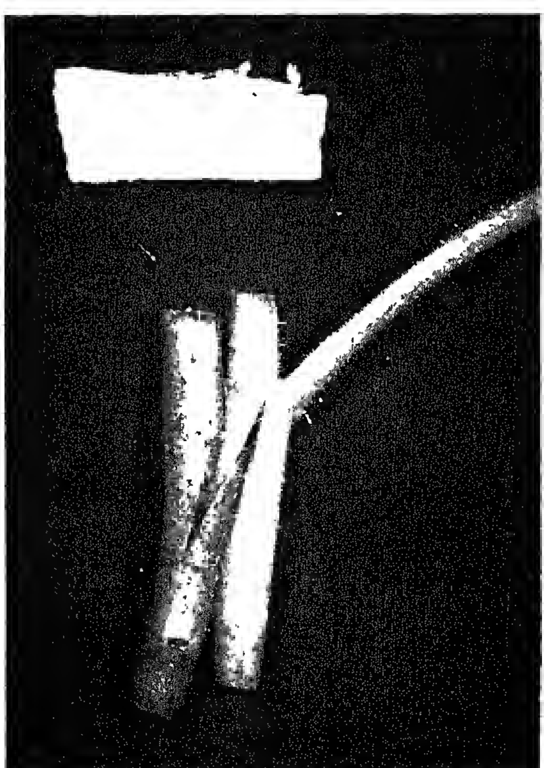
Left Too early, *Centre* Correct stage, *Right* Too advanced

Tomato propagation plants in soil blocks for planting

PLATE V

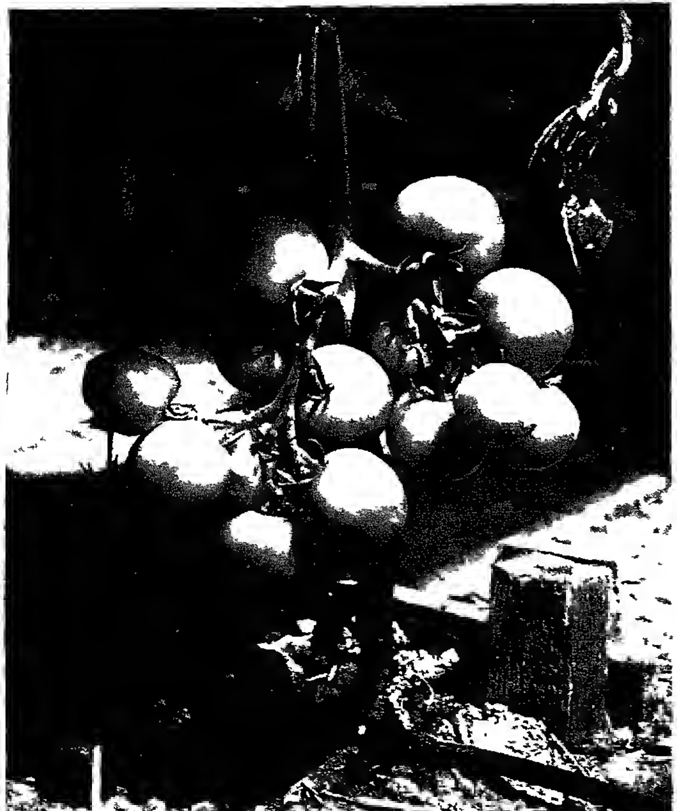
A good crop of high quality tomatoes, also shows watering by low level sprinkler system

Grafted tomato plant after graft has taken but before severance of scion rootstock

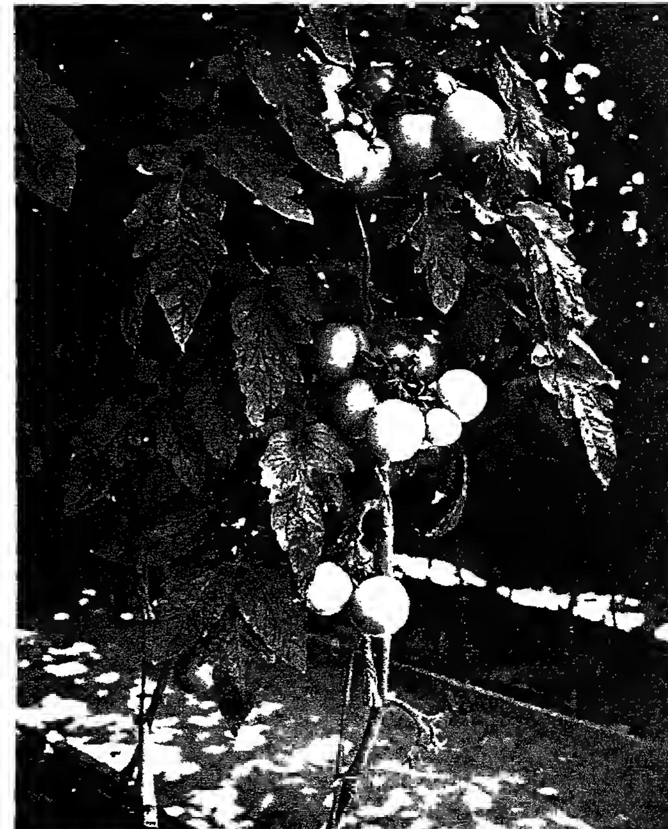


Close-up of side graft and binding material

PLATE VII



Cool grown crop, 17 May, first truss just commencing to ripen



Crop grown warm 18 May, first and second trusses almost cleared third and fourth commencing to ripen

CROP MANAGEMENT

Watering

Watering requires skill, experience and sound judgment. The development of fixed-pipe watering equipment and means of measuring water requirement do not remove the necessity for a grower to have an intimate knowledge of his soil and of the reaction of his crop to water.

Plant roots need air as well as water and watering must be done so that waterlogging of the soil is avoided and air not excluded by surface packing. Careless application of water may quickly destroy the good structure left by careful preparation. It can also lead to root rots which severely affect the development of the crop and lead to failure of the later trusses.

When tomatoes are growing in soil, water is extracted and the moisture content progressively reduced until further water is added to make good the depletion. When the moisture content is allowed to fluctuate only between field capacity (see p. 30) and a predetermined state of dryness, the crop is subjected to a specific moisture regime. Where the fluctuation is small the regime is termed "wet", where it is large the regime is termed "dry". It is impossible to maintain a specific moisture content in a border soil; it can only be allowed to dry out to a predetermined point and then returned to field capacity to a depth depending on the quantity of water added and the depletion of the soil moisture content.

Watering between planting and the setting of the first flowers can adversely affect early yield. Ball watering should be reduced to a minimum and, after watering in, should only be given until the young plants have established roots in the border soil. When tomatoes are set out into soil near field capacity, growth is not affected by added water so long as the roots are growing strongly into moist soil. When the roots have fully explored the soil volume the tomato becomes sensitive to water regime; maximum growth and yield, though not necessarily highest quality, is obtained when soil is kept near to field capacity.

Water regime also influences root distribution, vegetative growth and fruit quality. Wet regimes produce maximum root development in the top 4 in. of soil, whereas dry regimes give maximum development in the 8–12 in. zone. This orientation of the root system emphasizes the importance of subjecting the tomato plant to a consistent water regime throughout its life. Once a particular procedure has been established it is unwise to alter it, otherwise the crop may be checked. A plant which has developed most of its roots in the surface soil early in the season as a result of maintaining a wet regime would be badly checked if the soil were suddenly dried out later in the season. Dry regimes produce better quality fruit and more uniform ripening (though water is not the only or the most important factor involved) but tend to give lower yields. Very dry regimes contribute to such troubles as blossom end rot. Vegetative growth is affected by moisture regime and fruit load. The effects of the two are additive, weakest growth occurring with a dry regime and a heavy fruit load.

Methods of Application

Water can be applied by hose or by one of the fixed-pipe watering systems described on pp. 70–72. Hose pipes are still used in many glasshouses but can cause trouble by splashing, uncovering the roots or packing the

surface. Surface packing reduces aeration and the speed and evenness of penetration, but it is difficult to avoid on some soils. The danger can be reduced by holding the hose close to the ground and using a rose or spreader in the outlet. The size of the hose should be related to the rate of application. Small hoses should not be used where a high rate of application is needed. Hose watering has a high labour requirement and it is difficult to get the job done well because of its monotony. Fixed-pipe watering systems overcome most of these disadvantages; they also save labour, apply water more slowly and do not impair surface structure.

Estimation of Need

If winter flooding has been properly done and the plants set out into borders near field capacity the water requirement is very low until the first flowers begin to set. As the young plant becomes established and grows the water uptake is largely dependent on the leaf cover and the weather.

Where the grower has no means of estimating water need he must be guided by the appearance of the crop and the soil. A soil auger is a most useful tool as it enables numerous samples to be examined quickly to any reasonable depth. The most difficult period in watering is changing from the cautious procedure during the early weeks to the generous treatment required later. This should not be delayed too long or the subsoil begins to dry out. On the other hand, if too much water is given too soon, the plants may become over-vigorous and run past the first truss. By the time the plant reaches a height of about 3 ft requirement is related to weather.

The methods of calculating water requirement described on p. 70 provide an accurate estimate of water need and remove much of the guess work from watering. Even where a grower has none of the equipment described he can make good estimates from simple weather observations. Each day's weather is assessed and the water requirement determined from Table 5.

TABLE 5

Water need under glass for different weather conditions

Weather	*Water requirement per day*	
	gal/acre	pt/plant*
Very dull	600	¼–½
Dull	1,000	½–¾
Moderately bright	2,500	1¼–1½
Bright	3,500	2 –2½
Very bright	5,000	2¾–3¼

* Quantity per plant is less at close planting distances.

Weather assessment

Very dull — overcast all day.
Dull — generally overcast but occasional breaks in cloud cover.
Moderately bright — cloudy but with bright periods.
Bright — mainly clear with occasional cloud or thin high cloud.
Very bright — clear sky all day.

The figures apply to the months of May–August. They should be reduced by half in March and one-third in April. The daily requirement is accumulated between waterings and the accumulated total applied at each watering.

The requirements given in the table assume the presence of a full leaf cover over the soil. This does not occur until the plants are about 3 ft high and the figures need correcting by a factor until this height is reached.

Height *in.*	*Factor* *X*
12	0·4
15	0·5
18	0·7
24	0·8
30	0·9
36	1·0

It should not be necessary to apply water more often than twice weekly except in periods of very hot weather. A good guide is to apply water each time a deficit of 0·2 in. (5,000 gal/acre) has been built up. Whatever method of estimation is used the grower should check that the correct condition is being maintained by the appearance of the crop and from auger samples.

The maintenance of different soil moisture regimes will make little difference to the water requirement over the season, though the frequency of application and the quantity applied at any one time will vary with the regime. For guidance in assessing likely usage it is estimated that the tomato plant requires about 22 gal per plant over the season. This is equivalent to 330,000 gal per acre, which with 66,000–100,000 gal per acre for winter flooding gives a total of 396,000–430,000 gal per acre per annum. It is most unlikely that the requirement during any one week in summer would exceed 35,000 gal per acre.

Mulching

Materials such as straw, peat and strawy manure are sometimes used as mulches on tomato crops. They may be applied simply to conserve soil moisture and keep the roots cool, and for this purpose straw is the most efficient. It also reduces splashing and other defects of heavy watering. Mulching encourages the formation of surface roots, especially when the soil is very shallow, for example when a bed is made on a solid base or when there is poor root development owing to disease or other limiting factors. For this purpose it is preferable to use peat, well-rotted manure or a mixture of soil and well-rotted manure into which the roots will run freely and through which they can be fed. Fresh manure must be avoided because the ammonia given off may cause serious scorching.

In some circumstances the use of soil mulches may encourage the attack of fungi, such as *Corticium solani*, and lead to an increase in plant losses due to foot rot.

Overhead Damping

Although the generally accepted idea of a brisk, dry atmosphere for tomatoes is correct, experience has shown that there are times when this should be modified. Thus during the period immediately following planting, when very little water is being given, light overhead damping of the plants and soil on bright days provides the right atmosphere to stimulate growth.

A watering can or syringe can be used where there are only a few plants, but otherwise a hose is needed. Having turned on the water to provide a reasonable pressure, the operator nips the end of the hose to make the water form a spray, which is thrown from side to side over the plants.

In order to simplify the operation and save time, some growers have installed overhead spray-lines, particularly in Dutch light structures. The spray-lines run the full length of the house and are connected to a main carried just above the doorway on the inside of the block. They are fitted with jets specially designed to give a fine mist-like spray. As the delivery range is approximately 7–10 ft in all directions jets must be fitted every 10 ft along the spray-lines. Two to three minutes' spraying provides adequate damping for a growing crop.

For a house 28–30 ft wide three such spray-lines are required, one down the centre and one down each line of purlin posts. For a house 20 ft wide two lines should be fitted in suitable positions to provide a 5 ft throw either side of each line, covering 20 ft in all. One central line will cover the requirements of a Dutch light structure with a span of 10 ft.

Shading

Because the ventilation of houses built in large blocks is usually inadequate many growers apply shade to the glass, primarily with the object of preventing excessive rises in daytime temperatures. Experimental work sponsored by the Glasshouse Crops Research Institute and now in progress at the Lee Valley Experimental Horticulture Station indicates that shade used in this way is harmful to crop yield and profitability. Yields have been highest and fruit colour and quality best when the plants have been unshaded, excessive daytime temperatures being avoided by early and abundant ventilation.

Where varieties subject to green back are grown, however, it is prudent to apply light shading when sunlight is fierce. This helps to avoid high temperatures in the fruits of trusses exposed to full sunlight and less green back will occur. The southern ends of the houses will most need protection, but the amount applied should be as light as possible and of a kind which will readily wash off if the weather becomes dull and rainy. A mixture of flour and water can be recommended for this purpose.

Varieties such as those described as uniform ripening on p. 6 perform best when grown with good light, as they are resistant to green back. Uniform ripening forms of Ailsa Craig and Potentate have recently been developed at the Glasshouse Crops Research Institute and, if these show themselves to be satisfactory on other counts when available in commercial quantities, they will enable crops to be grown with greater safety without shade.

Shade is frequently used as a first aid measure to prevent wilting in plants which have suffered root loss or damage through attacks by soil-borne pathogens or insects. For this purpose the temporary use of a full coverage of shade is justified, but a low level of yield is likely to be the penalty for such culture. In the subsequent winter every endeavour should be made to rectify the soil troubles and the need for excessive shade thereby avoided.

Ventilation

Ventilation can have four beneficial effects on the tomato crop:

1. limiting the rise of air temperature in sunny weather;
2. reducing excessive humidity which could encourage fungus diseases;
3. admitting to the glasshouse the supply of carbon dioxide which is needed for plant growth; and
4. permitting air movement to ensure that the fresh air supply does in fact reach the plants.

Plant environment is at present the subject of much study both here and abroad, but hitherto little fundamental information has been available on the practical aspects of ventilation and the control of temperature and humidity in glasshouses. Research work is in progress at the National Institute of Agricultural Engineering in conjunction with the Experimental Horticulture Stations of the National Agricultural Advisory Service. From this work it appears probable that, especially in large blocks of houses, the amount of ventilation is generally inadequate. This could be remedied to a great extent by arranging for the roof ventilators to open through a larger angle to 30 deg. or more above the horizontal.

Although deficiencies in carbon dioxide concentration have been observed among tomato plants, this is unlikely to be serious if ventilation is sufficient for adequate temperature control. On the other hand, it is possible for humidity to be excessive when the air temperature is satisfactory, and then it is necessary to open the ventilators slightly and maintain the desired temperature by using the heating system. It is the practice of some of the best tomato growers to open the ventilators during the mornings for the first three months after planting out and to maintain the required air temperature with pipe heat. The value of this practice is being tested in current experiments at the Experimental Horticulture Stations.

During a hot summer the ventilation in old houses may be inadequate and the practice of removing some panes of glass may be adopted. As loss of crop and lowering of quality occurs on account of excessive day temperatures in summer, everything possible should be done to ensure that ventilation is sufficient and effective.

Careful judgment in the use of ventilation is necessary during the period immediately following planting, especially with early crops, since unduly low temperatures and draughts cause a severe check to young plants, but once the plants are established ventilation should be used as freely as weather conditions permit.

In experiments at the Lee Valley Experimental Horticulture Station the provision of early and abundant daytime ventilation, commencing at temperatures of 65–67°F, has consistently given higher crop yields than where ventilation has been delayed and day temperatures have become higher. Thus in 1960 the mean level of yield from ten varieties subjected to a ventilation regime in which the opening of the vents was commenced at 67°F was 63·2 tons per acre. The same varieties grown with day ventilation commencing at 75°F produced a mean yield of only 45·6 tons. All varieties were adversely affected by the higher day temperatures, but Moneymaker proved especially sensitive.

Temperature after Planting

Temperature and light are two most important and interrelated factors in the growth and cropping of tomatoes. Under glass temperature can be controlled but very little can be done to control light except during the propagation period. To make the best use of the natural light available it may be necessary to regulate the temperature to secure suitable growth and high yield.

The effects of temperature and light on growth and development have already been discussed under propagation (p. 22), but correct temperature is of the greatest importance in the production of good pollen and the setting of the flowers. Good pollen and good setting are not obtained much below 55°F, particularly early in the season. On the other hand, too high a temperature (above 80°F) also results in sterile pollen and poor setting. The safe temperature range for good setting and fruit swelling is 55–75°F with the optimum between 60 and 65°F.

From recent experiments it would seem that established practice with regard to night temperatures provided for a tomato crop after planting out must be reconsidered. There is no doubt that a minimum night temperature of 54–56°F will slow down the growth rate and produce a sturdier plant under the poor light conditions obtaining in the early months of the year. This environment, it was thought, should result in the production of a plant capable of giving the biggest crop over the season, though it was appreciated that because of the comparatively low temperatures the crop would mature a little later.

The experiments referred to have proved that for December-sown plants at least this is not so and, while the optimum temperature for maximum yield and early production is yet to be determined, it has been shown that in houses with good light transmission a night temperature of at least 62°F can be used with advantage during March and April if ventilation is used to keep the day temperature between 65 and 70°F. Maintaining a higher temperature increases the cost of heating — a difference of 6°F may add 50 per cent to the fuel bill — and after the optimum night temperature has been finally determined it will be necessary to study the economics of its application in commercial practice. Not all varieties may react in the same way to relatively high night temperatures: for example, whereas the shape of Potentate fruit is improved, the variety Moneymaker tends to produce rather angular fruits if the mean temperature is too high.

The general guide previously given may still be useful to those growers who are not prepared to meet the cost of maintaining a night temperature of 62°F and is as follows:

Up to the end of February, the maximum night temperature should not exceed 57°F; during March it may be raised to 61°F and thereafter to 65°F. It must be kept in mind at all times that these figures provide a very general guide and night to night variations are rendered necessary by changing conditions of light intensity during the day.

Another approach to the problem of obtaining a heavy crop and early maturity with good quality lies in the provision of pipe heat during the day. This is an accepted practice by the best growers in Guernsey and Holland. The main difference as compared with traditional growing is that, instead of making use of sun heat to raise the glasshouse air temperature in the

mornings with ventilators closed, the heating pipes are maintained 140–170°F and if the air temperature rises above the desired value ventilators are opened to dissipate excess heat. It is claimed that the air temperatures chosen are no higher than those used traditionally but that the plants benefit in some way from the proximity of the warm heating pipes.

The possible benefits are as follows:

1. the rate of transpiration of the plants can be increased so that some measure of control of vegetative growth is obtained;
2. the air movement and reduced humidity assist in disease control;
3. the soil temperature is increased;
4. the temperature of the plant is raised above the general air temperature by radiation from the pipes; and
5. the CO_2 supply to the leaves is improved by the increased ventilation and greater air movement.

In 1960 and 1961 the effects of pipe-heat were studied at Efford and Fairfield Experimental Horticultural Stations with tomatoes planted in the glasshouse borders. The effects on transpiration, soil temperature, plant growth and weight and quality of fruit were all negligible. The cost of heating the houses between mid-February and the end of May was increased by over 50 per cent. Other effects were not measured and it may be that pipe-heat is of some value in disease control. It is also conceivable that it would have some effect on plants grown in containers, because of increased soil temperature.

During May and subsequent months, the main problem is to keep the day temperature low enough on sunny days. High day temperatures tend to depress total fruit yield and increase the incidence of ripening disorders, including splitting. If temperatures greatly in excess of 70°F persist for long periods of time, consideration should be given to increasing the number, size and angle of opening of the ridge ventilators and to increasing the area of air inlets in the sides and ends of the glasshouse.

Support

The most economical method of supporting plants is by strong five-ply fillis or Italian hemp attached to 12–14 gauge galvanized wires fixed overhead. If provision is not made for overhead wires when the house is constructed, a good method of fixing them is to secure a piece of 3×2 in. timber across the house at each end from purlin to purlin, bolting it to the doorposts where it crosses them above the doors. A tie from these cross-bars to the ridge board helps to relieve the strain on the end of the house. From each end of the cross-bar a piece of 1 in. iron barrel is taken to the gutter plate and fastened securely to it as well as to the cross-bar. Wires are then run the length of the house and tightly fastened to these two end-bars; the position of the wires should coincide with the position of the rows if these run lengthways. The wires attached to the two horizontal cross-bars are not usually supported intermediately unless there are horizontal supports over which they can be passed. Those attached to the iron barrel are supported by wire hooks in the roof bars, so that the wires are held about 11 in. from the glass. The hooks are fixed to every fifth bar and are so arranged that there are not more than two hooks in any bar. Before bringing in the plants five-ply fillis,

cut to suitable lengths, can be tied at the points where the wires cross. To prevent the strings getting in the way the free ends of a suitable number are gathered together at intervals and tied in a loose knot until training starts.

There are several ways of fixing the bottom end of the fillis, but the one recommended is to use galvanized wire stakes $\frac{3}{16}$ in. diam. and 2 ft 9 in. long with the top bent over to form a hook to which the fillis is attached. One stake is inserted at the base of each plant, which is at first tied to it, but as the plant grows taller it is supported by twisting the fillis round it. This twisting is best done during the afternoon when the plants, being less turgid, are not so brittle.

Sometimes the fillis is tied round the base of the plant with a loose loop big enough to allow for the thickening of the stem. This method requires great care or damage may be done to the plant.

The old method of using a bamboo cane to each plant has been discarded, partly on account of cost but mainly because the canes provide places where insects, including red spider, may congregate.

Pruning and Training

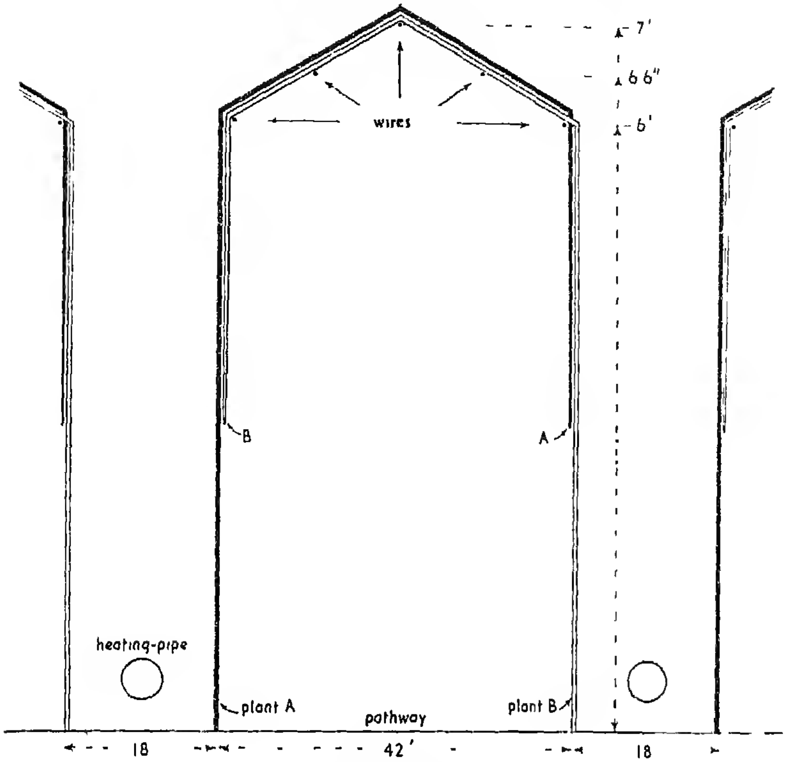
Usually the plants are grown with a single stem, side shoots being removed as they develop in the axils of the leaves. They should be rubbed out regularly when quite small to avoid the production of useless growth and the large wounds which are inevitable if the shoots are allowed to become well developed. In the event of an attack of leaf mould it may be advisable to leave the side shoots near the top, since the foliage may help to swell the top trusses.

Some growers run up two shoots, either to the full height of the plant or to the second truss. The former method is suitable where a plant has failed and there is a gap to fill or if there is more space available at the ends of rows.

A method of archway training which makes it possible to carry out all pruning, training and picking operations from ground level is practised to a considerable extent in Guernsey and is now being used on a few nurseries in this country. It can only be adopted with lengthwise planting, and involves re-arranging all roof wires in the following manner: two wires immediately above the plants are fixed at 6 ft from ground level, and another midway between and over the pathway is fixed at 7 ft; two further wires 6 ft 6 in. from the ground are placed at intermediate points (see Fig. 3). The plant is trained upright on fillis in the usual way until the first wire is reached. It is then tied down to this wire and to each successive wire in turn. Eventually the tip is turned downwards and as growth proceeds the plant is trained down the string supporting the plant opposite. Older leaves are removed as they mature and as this is done before the downward training starts there is no overcrowding of foliage.

The advantage of this method of training is the reduction in the cost of operations because all work is done from ground level. In a comparison between the conventional English system of training and the archway or Guernsey method the yields of fruit were virtually the same from both systems, but the costs of pruning, tying, etc., were about 30 per cent less for the Guernsey system. A trial of the method on nurseries where a main crop of tomatoes is grown seems justified.

The process of removing a proportion of the foliage requires care and moderation. The leaves manufacture food for the development of the fruit



Archway training

FIG. 3

and if they are removed unnecessarily the quality and size of fruit suffer. The proper balance between foliage and fruit should be obtained by cultural means but, if the foliage has become dense, taking out some of the leaves provides better circulation of air and more light can get to the fruit. Shortening the leaves is useless; it may add to the convenience of working but does not improve air circulation around the stems and trusses. The best method is to take out a complete leaf here and there, snapping it off with a sharp pull sideways and leaving no stump or snag which may be liable to attack by *Botrytis*. It is seldom necessary to remove more than one leaf between two adjacent trusses. The removal of leaves is best done early in the day when the plants are turgid and the foliage snaps off easily.

In addition to thinning the foliage it is desirable to remove the older leaves. By the time the first truss is fully developed and about to colour the leaves below it have generally done their work and are beginning to turn yellow. They should be taken off to admit more light and air, and the procedure followed up the plant as each truss develops (see Plate VI).

A knife is sometimes used for defoliation and side-shooting, but it must be skilfully done and a clean cut made close to the stem. It is easy to leave snags when working fast and virus disease may be spread from plant to plant on the knife blade unless it is wiped after the completion of each plant with a cloth soaked in 10 per cent trisodium phosphate.

Stopping

Stopping is the practice of removing the growing point, while it is still quite small, at the second leaf above a flower truss. This is usually done when the plants reach the top wires or the required height. At one time it was usual to stop the plants at the fourth or fifth truss, subsequently carrying up a side shoot. This was thought to hasten the development of the bottom trusses, but experiments and experience have shown that the gain is negligible and the behaviour of the plant is more satisfactory when allowed to grow unstopped.

Fruit-setting Substances

Growth-promoting substances induce fruiting without normal fertilization, so that seedless fruits are produced. Several proprietary preparations, in which the active compound is beta-naphthoxyacetic acid, are on the market. The solution is directed in the form of a fine spray on to the open flowers and care must be taken to avoid the solution falling on to other parts of the plant. An excess may cause hollowness in the fruit and a certain amount of malformation. It is essential, therefore, to use these materials strictly in accordance with the instructions of the manufacturers and only to use them as an emergency measure rather than as a way of avoiding the necessity of securing natural fertilization. It should also be noted that they have no influence on the formation of the truss and are effective only when normal healthy female parts of the plant are present. Under these circumstances their use often ensures a set of fruit on the bottom trusses of very early crops when conditions for setting are bad and natural fertilization might be very uneven.

Special Methods

POT CULTURE

Tomatoes may be grown quite successfully in pots or other containers but the method is not economic except under special conditions such as the following:

1. if there is a specific disease or pest which is difficult to control, e.g., eelworm;
2. where the border soil is unsuitable for growing tomatoes;
3. to secure extra early crops or to grow them as a catch crop in company with another early crop such as cucumbers.

Those growers with houses having hard-surfaced floors and with fixed staging are usually obliged to adopt this system; others may be forced to do so where, as stated above, the border soil is unsuitable or has become "tomato sick". Most of the early fruiting varieties can be used for pot work, but in small, low houses Potentate and Baby Lea are particularly suitable.

In houses which are to be specially used for pot culture the floor, if of earth, should be dug over and either steam sterilized or treated with formaldehyde

(40 per cent) at a strength of 1 in 49 gal water. Five gallons of solution should be applied per sq. yd in order to sterilize the surface and give sufficient clean soil for the roots that will pass through the hole in the pot. This sterilization is not sufficient to control eelworm (see p. 87). Brick or other hard-surfaced floors should be washed clean and treated with formaldehyde.

Times of sowing and planting are the same as for planting in borders, unless very early fruits are required when an extra early sowing can be made. However, this is not advisable except in districts with good winter and spring light and in houses which admit the maximum of sunlight. In these areas and in suitable houses sowings may be made about the middle of November.

The houses may be ventilated whenever weather conditions permit, and overhead spraying of the plants and shaking the wires helps to set the flower trusses. Some growers use fruit-setting hormone sprays (see p. 50).

Potting from 3½ in. into 10–12 in. pots or other containers should take place from the end of December onwards, according to the time of sowing and the locality. J.I.P.2 compost is suitable for this early work where the light is good. Some growers allow the balls of soil from the 3½ in. pots to rest in hollows in the pots in the same way as for border planting with soil blocks, the soil being gradually washed around the roots by watering. To avoid rooting into the borders the pots are lifted every few days or placed on squares of polythene. Rooting through should be prevented until at least one truss is set, and in the case of very early crops may be prevented until four or five trusses are set. Weak growing varieties such as Baby Lea may, however, be allowed to root into the borders earlier than stronger rooting varieties.

Spacing can follow that suggested in the planting plan in Fig. 2. The long row method (Fig. 1) with the plants 15 in. apart in the rows is most suitable when growing in containers as referred to on pp. 37–38.

Little water is required until after the first truss has set when increasing quantities can be given, bearing in mind that evaporation occurs through porous pots. The pots should never be allowed to become either very dry or waterlogged. Feeding with a suitable top dressing mixture or liquid fertilizer can start from the setting of the first truss and further applications can be given every 7 days.

Normally plants in pots will need a good deal of nitrogen in the later stages of growth and there is less danger of producing lush growth with long internodes and poor quality fruit than with plants in borders. A mixture of two parts dried blood to one part sulphate of potash is suitable, applied at the rate of ½ oz per plant to begin with. Later applications should consist of higher proportions of blood and less potash according to the condition of the plant. Sulphate of ammonia is sometimes used instead of dried blood because it is cheaper. As an alternative, liquid feeding may be given, following the methods suggested on p. 36, always bearing in mind the particular need for nitrogen in the early stages with such varieties as Baby Lea and Potentate.

With very early crops it is not advisable to use artificial illumination because difficulties with later management will ensue unless the winter light is exceptionally good. Methods of growing follow those in borders but particular care must be taken with the watering of early crops. The general practice is to keep the young plants rather dry until the lower trusses have set.

Staking, tying and side-shooting should be attended to in the normal way (see pp. 47–48).

Sometimes tomatoes are grown in pots on the paths of cucumber houses, but this is not advisable if the cucumbers are to be planted before 15 February because the growth of the cucumber foliage excludes light from the tomatoes. Tomato seeds for this purpose are sown at the end of October or the first week in November, and the plants are ready to be set out in the pots from 7–15 January. The pots should be stood in two rows in the middle of the house, allowing 12 in. from plant to plant in the row and 6–10 in. between the rows of pots.

The cucumber seeds are sown just before Christmas for planting about the middle of February and the plants are stopped at the seventh wire to allow the tomatoes sufficient light for ripening. Three trusses may be allowed to each tomato plant, but it is usually better to stop the plants after the second truss.

CULTURE IN CUCUMBER AND OTHER LOW HOUSES

On many nurseries there are low houses which differ considerably from the traditional tomato house. These are usually occupied with pot plants and bedding plants during the winter and spring months but are available for tomatoes during the summer. Good crops can be grown if suitable varieties and methods are employed.

Varieties

For low houses it is important to choose a relatively short-jointed variety. Potentate is suitable but the fruit is often of inferior quality. A variety of compact habit and one which is often used is Baby Lea, but the proportion of poor quality fruit produced is frequently higher even than from Potentate.

The varieties of compact habit bred in recent years at the Glasshouse Crops Research Institute are of particular value for use in low houses. They have the compact form of Baby Lea, one of the parents, but fruit of much better quality.

Preparation of Soil

Soil should be prepared on lines similar to those advised for other types of glasshouse, see p. 26.

Planting and Subsequent Treatment

The method of planting and subsequent treatment is important. In a house 13 ft wide 3 rows running lengthwise should be planted on either side of the central path. These rows should be 14 in. apart with the plants spaced alternately 18 and 27 in. apart, so that when planting is finished the working paths run across the house. In the back rows an additional plant should be placed at the end of each path. The row nearest the path should be stopped at 5 trusses and the next row at 4 trusses. The back rows are not stopped but allowed to cover the wires, and as soon as they reach the roof side shoots should be allowed to grow until they have produced a truss, then stopped at the second leaf beyond it. This process is continued throughout the season. All main and side shoots should be tied in neatly to cover the wires uniformly. If this task is well done and the plants kept in good condition a heavy

roof crop will result and picking will continue well into November. Alternatively, a modified form of the Guernsey method of training can be adopted as this is particularly applicable to houses of medium height (see p. 48).

When the 4 centre rows (2 on either side of the path) have yielded their crop of 4–5 trusses they should be removed to give the roof crop as much air and light as possible. After this it is a good plan to prick up the soil lightly to a depth of 2–3 in. and apply a light mulch of horse manure or peat.

Experience of the cultivation of tomatoes in low houses has shown that the practice of obtaining the bulk of the crop from 2 rows of plants trained over the roof wires produces heavier crops than any other method.

Feeding

The short-jointed varieties of tomato usually grown in low houses require frequent feeding throughout the season. Soluble fertilizers, as recommended on p. 36, can be included with each application of water and a constant supply of nutrients thereby ensured. Where this is not possible solid fertilizers can be used; these can be purchased either as compounds with nitrogen and potash suitably balanced, or the necessary straight fertilizers should be obtained and mixed and applied in such a way as to provide the right balance to suit the season of the year and condition of the crop. A suitable rate of application in most circumstances would be 1 oz per sq. yd applied at weekly intervals just before watering. See also p. 34, Top Dressing and Feeding.

Management

The general management of the crop can follow that given for other types of houses (p. 41 onwards), but it should be remembered that varieties of compact habit particularly require cultural conditions which are conducive to steady growth and plant development. Unduly low temperatures at night, i.e., below 60°F, and excessively high temperatures by day, i.e., 75°F, are unfavourable to these varieties and should be avoided.

Until the plants meet in the rows overhead damping should be done systematically and continued for as long as necessary. However, it is usually unwise to continue this practice after the first week in June as it may encourage the development of *Cladosporium*.

UNHEATED GLASSHOUSES AND DUTCH LIGHT STRUCTURES

The main difference between the cropping of tomatoes in heated and unheated glasshouses is in the lack of temperature control in the latter, and since temperature and atmospheric humidity are closely interrelated a lack of humidity control is also implied. The importance of temperature is stressed elsewhere in this bulletin (p. 46). Where satisfactory temperatures can be achieved light is the limiting factor to the growth of the plants. Unheated houses are dependent on the sun's radiation for both light and heat and in such houses temperature remains a limiting factor to growth long after light has become more than adequate. Even in unheated houses satisfactory day temperatures can be achieved quite early in the spring but only during periods of bright sunshine. The soil in the border is warmed by radiant heat from the sun and during the long nights of the early spring

most of this heat is dissipated again. The soil loses heat to the atmosphere of the glasshouse and it is usually quite late in the year before the reservoir of heat in the soil is sufficient to enable a satisfactory night temperature to be maintained. The planting of tomatoes should not be commenced until this stage is reached.

Tomatoes do not differ in their basic requirements simply because they are planted in unheated houses, and in considering their culture in such houses the aim should be to provide the conditions described for heated houses. Usually it is about the middle of April before they can be planted in unheated houses and structures and, if measurements are taken at this time, it will be found that the soil temperature in the borders exceeds 50°F during the day and does not fall much below this temperature during the night. These conditions may be reached rather earlier in the extreme south of England and a little later in the north. Once they have been reached planting should not be delayed, since the growing season is prescribed not only at the beginning but also at the end and delay in planting means a reduced crop. Indeed, once conditions are suitable for planting a week's delay may reduce the overall crop by as much as 10 per cent, mainly in terms of early fruit which normally commands the best price on the market.

Watering and Feeding

The main requirements for watering and feeding in cold houses are similar to those in heated houses, except that the season is shorter in cold houses and the duration of these operations is reduced accordingly. (See section on Nutrition, p. 31).

Soil Preparation

It should not be supposed that the requirements for the preparation of the borders are any less exacting than in heated houses. If anything they should be more so, for lack of temperature control frequently exposes the plants in unheated houses to adverse conditions which may weaken their resistance to pests and diseases. It is therefore important to remove all sources of infection by careful preparation of the soil.

This is a costly process and the initial cost must be considered against the total expectation of crop. According to the pests and diseases which may have accumulated in the tomato border, the cost is similar for heated or unheated houses but the difference in crop may be very considerable. It is perhaps best to make comparisons between potential crops from the two types of houses; whereas in heated houses crops of 80 and 90 tons per acre are sometimes obtained, in cold houses 50 tons per acre is probably near the maximum in the south of England and 40 tons in the north. In both areas the seasonal fluctuations will obviously be much greater in unheated than in heated houses. The margin of profitability will therefore be low in unheated houses if recurrent pests, such as potato root eelworm, or diseases, such as *Verticillium* or *Didymella*, once became established on the holding. Growers have developed various means for countering these troubles. Sometimes the structures are moved to a new site, but more usually a system of alternate cropping is adopted and the roof lights are moved from one structure to another, the soil on the uncovered site being rested from tomatoes for at least twelve months. The mobile structure is another means to the same end. Growers who use Dutch light structures realise the high

cost of initial preparation of the soil and their complete dependence on the weather in obtaining a satisfactory crop, and many have installed at least a skeleton heating system which secures them against the worst vagaries of the British summer. This, however, is a development which is to be seen more in the north than in the south where the cropping potential of unheated structures is higher.

The preparation of the borders in unheated houses is important because maximum yields are low, and for the same reasons it is important to produce a good plant in the propagating stages. A tradition has grown up amongst Dutch light growers, particularly in the north of England, whereby tomato plants for cold structures are raised in boxes for direct planting as this is thought to be an inexpensive method of propagation. All the evidence is in favour of the use of first class plants grown singly in containers, such as would be produced for planting in a heated house. It is true that cheaply produced, box-raised plants survive and after a time grow remarkably well, but experience shows that there is a sacrifice of early crop which outweighs the saving made at the propagating stage.

Planting

Dutch light structures are commonly built in 10 ft spans so that 4 rows of tomatoes can be planted under each span. The first row is 1 ft away from

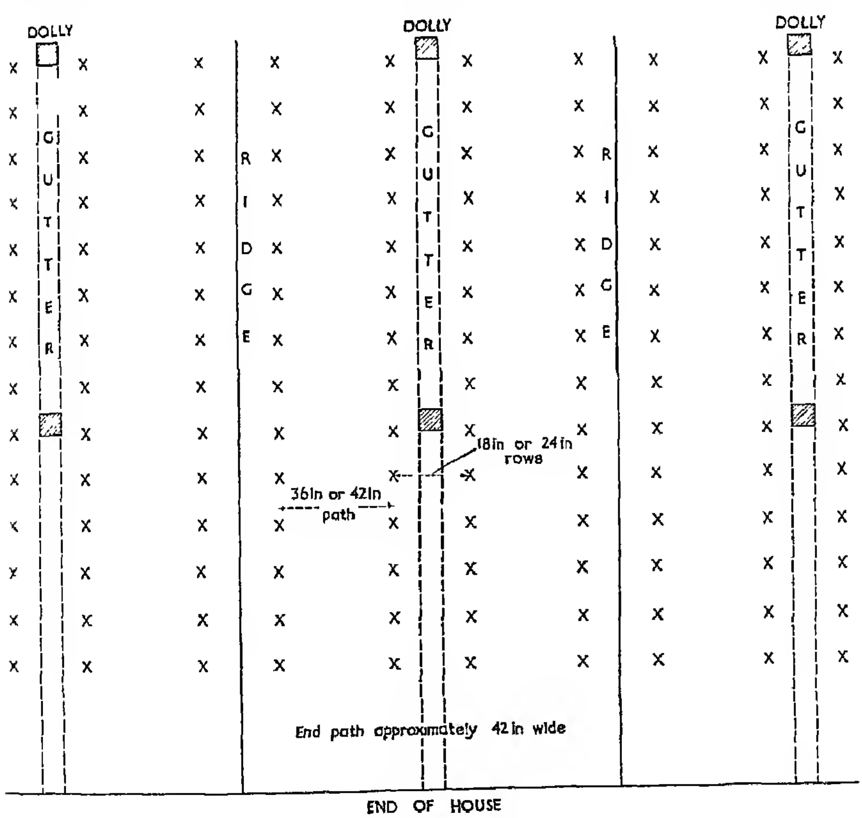


Fig. 4

Long-row method of planting in Dutch light structures

the gutter, next comes a 3 ft path, followed by 2 rows down the centre of the span 2 ft apart; on the opposite side of the span there is a second 3 ft path, with a fourth row 1 ft away from the next gutter. The traditional spacing along the row is about $15\frac{1}{2}$ in. apart which gives 28 plants to a 10×9 ft bay. This gives a population of 13,500 plants per acre.

For a steel structure the length of the bay would be increased from 9–10 ft and the distance between plants reduced from $15\frac{1}{2}$–15 in., allowing an extra 4 plants per bay 10×10 ft.

Management

The establishment and training of plants is the same as in heated houses. Ventilation requires careful manipulation however, in order to conserve as much of the heat as possible during the night. Throughout the season this remains one of the chief problems in cold houses. The need for maintaining a satisfactory night temperature runs counter to that of keeping the humidity of the house low. The compromise most often accepted is that which favours a lowering of humidity by means of ventilation. The ventilators may be closed at night during May and early June until the house becomes substantially full of plant growth, after which it is usual to leave the ventilators fully open and even to increase the overall ventilation of the structure by removing some of the glass from the side lights. This is usually done by removing the bottom glazing cleat from the light and allowing the glass to slide down to ground level, thus providing a gap of about 18 in. at the eaves. It must be remembered that Dutch light structures are essentially low and that the amount of headroom above the plants is extremely small. In unheated houses of the traditional vinery type ventilation is not so difficult as the amount of headroom is comparatively large.

In Dutch light structures the plants are stopped shortly after they reach the wires, as there is insufficient headroom in the house for further growth and fruit formed after that date will not ripen. The crop continues until towards the end of October when it is advisable to cut any remaining trusses and ripen, as for late outdoor crops, in a heated glasshouse (see p. 62). These late fruits can bring in quite a useful return and care in ripening them is fully justified. Although the quality is not high, prices usually harden again at the end of October and the beginning of November. Leaf-mould-resistant varieties in particular frequently set some heavy top trusses for ripening in this way at the end of the season.

Disease Control

Because there is no satisfactory compromise between humidity and temperature control in unheated structures, tomato leaf mould and *Botrytis* are troubles which inevitably appear. Modern fungicides and the use of leaf-mould-resistant varieties for cold houses provide a satisfactory solution to the control of leaf mould, but *Botrytis* is a more serious problem and one which it is difficult to solve. No fungicide appears able to control this disease adequately; there is some evidence, however, that where low level irrigation equipment is used for watering in cold houses, so that the major portion of the soil surface remains dry, the incidence of *Botrytis* is reduced; the absence of splashing of the foliage and the reduction of traffic along the paths between the plants during watering, with less mechanical injury to the foliage, may also play a part. It is quite clear, however, that a good deal of the *Botrytis*

which occurs on tomatoes in cold houses arises from the shedding of flowers which fall on to healthy leaves, the decaying petals forming sites on which the spores of *Botrytis* can develop and grow into the healthy tissues. The usual precautions against *Botrytis* must therefore be undertaken with special care in unheated houses.

CULTIVATION IN THE OPEN

Under present day competitive conditions it is inadvisable to grow crops of outdoor tomatoes unless circumstances are very favourable. Since the yield of marketable fruit per plant depends on the number of trusses brought to maturity, only those areas with low rainfall and a high amount of sunshine can be considered suitable for the crop. The labour requirements are heavy and ability to cope with seasonal work may make the difference between success and failure. Prevention of late blight, which may otherwise ruin the crop, is essential, but this may be difficult in localities and seasons in which the disease appears early. When outdoor tomatoes are to be grown for the first time, it is advisable to make a trial with a small area.

Varieties

Bush, dwarf and normal glasshouse varieties can be used. The bush type of plant consists of numerous growths which develop in the axils of the leaves within a few inches of ground level. Because of the spreading habit plants should be spaced at 2 ft in the row and an arrangement of two rows 2 ft apart with a 4 ft pathway is convenient if all cultivations are to be done by hand. Wider spacing between rows is necessary if machinery is to be used. No staking or stopping is required, but as the trusses rest on the ground it is essential to place a mulch of clean straw closely round the plants as soon as the first fruits begin to develop.

The bushy habit of this type results in a denser growth of leaves and the effective application of fungicides is made more difficult. This means that in a year of severe potato blight losses of fruit may be greater than with standard varieties.

Amateur Improved is the most widely used variety in this group. It crops heavily, partly because of its ability to set fruit readily under adverse conditions, but the quality of fruit is not as high as from the best glasshouse varieties.

The dwarf type is a shorter growing form of the normal type, having stiff, thick stems and short internodes. It requires staking, stopping and the removal of side shoots as for normal varieties, but because of its short internodes shorter posts may be used.

Varieties in this group include Histon Early which is a potato-leaved type, and First in the Field which approaches the bush type of growth.

Generally, varieties of the normal glasshouse type are grown. Some, such as Hundredfold, Harbinger and Early Market, are particularly suitable, and others which have given good results are Market King and Moneymaker.

Soil and Situation

Although most types of soil can be adapted to suit the tomato, a well drained soil of medium texture and good depth is most suitable.

It is essential to provide conditions suitable for quick establishment of the plants and early development of the fruit. The site selected for the crop should have a southerly slope if possible and, as protection from north and east winds is desirable, temporary windbreaks of coir screening or similar material should be used where natural shelter is absent. Shelter is needed most during the first month in the open field. It may be a disadvantage later in the season, when the free circulation of air is required to help check the spread of potato blight disease. Sometimes existing walls and buildings may be used for shelter. In the interests of general hygiene, however, outdoor tomatoes should not be planted near tomato glasshouses.

Manuring

Land which is highly fertile as a result of generously manuring a previous crop is most suitable. When dung is needed it should not be given in a fresh strawy condition shortly before planting. Well rotted farmyard manure at 15 tons per acre may be ploughed in during the winter, or at least well in advance of planting. Tomatoes will thrive after a short term ley, especially if it includes white clover, but where an old ley is ploughed out a careful examination for wireworm is necessary. If these are found, the site should be treated with lindane before planting.

At the final soil preparation fertilizer should be worked into the surface. On moderately fertile soils the following is suggested per acre:

40 units nitrogen (N)
60 units phosphoric acid (P_2O_5)
180 units potash (K_2O)

which could be provided by

2 cwt sulphate of ammonia
3 cwt superphosphate
3 cwt muriate of potash

or a compound fertilizer could be used, e.g., 6 cwt per acre of one containing 6 per cent N, 15 per cent P_2O_5 and 15 per cent K_2O plus 1½ cwt per acre muriate of potash.

A nitrogenous top dressing will often be required when the fruit begins to swell, e.g., 3 cwt per acre sulphate of ammonia, or an ammonium nitrate-lime mixture (to provide about 60 units N).

On highly fertile soils the recommendation per acre is:

40 units nitrogen
20 units phosphoric acid
60 units potash

which could be provided by

2 cwt sulphate of ammonia
1 cwt superphosphate
1 cwt muriate of potash

or a compound fertilizer could be used, e.g., 4 cwt per acre of one containing 10 per cent N, 10 per cent P_2O_5 and 15 per cent K_2O, or 3½ cwt per acre of one containing 12 per cent N, 12 per cent P_2O_5 and 18 per cent K_2O.

A nitrogenous top dressing may be required as described above.

Raising Plants

Seed should be sown approximately six weeks before the date on which it is intended to plant out. It should be germinated at a temperature of about 65°F and then grown on at a night temperature around 60°F. The common practice, and one which avoids checks to growth, is to transplant the seedlings direct into soil blocks or 3½ in. pots using J.I.P.2 compost.

Because coddled plants may suffer a severe check when planted out, hardening off is important. In favourable districts the young plants may be transferred to cold frames about mid-April, but in colder areas the move should be delayed until the end of April. It is advisable to have some form of protective material at hand for covering the frames in the event of frost. Air should be admitted freely on all suitable occasions to produce sturdy plants and the lights should be removed entirely for at least a week before planting.

Planting

Planting should not be done until the risk of frost is past. It may begin in the third week of May in early districts, but in other parts of the country it is advisable to plant a little later. All planting should be completed by the end of the first week in June. The plants should be watered a few hours before planting and, if the land is very dry, irrigation is advisable in order to provide suitable conditions for growth.

Cloches can be used on small areas to permit earlier planting. This protection is provided until the plants reach the glass, after which the cloches are removed entirely or set up on end around the plants to afford some protection for a short time. Canes placed firmly in the ground on each side of the up-ended cloches prevent them from blowing over in strong winds. The removal of the cloches from the site becomes necessary when the plants need staking and wiring.

Plant spacing and arrangements vary considerably. It is important to provide plenty of space between the rows to allow free passage for spraying or dusting machines and other equipment. Four feet should be allowed between single rows and 15 in. between the plants in the row. Double rows 18 in. apart with plants spaced 2 ft apart in the row and an alley of 3–4 ft between each pair of rows is another popular arrangement. With double rows, supporting the plants is a little easier, but single rows are likely to set better and suffer less from disease, especially in a difficult season.

Planting may be done with a trowel, with the aid of shallow furrows, or by making holes with a planting tool, a pot dibber or other suitable implement as in glasshouses. The method used depends on the nature of the soil and the ease with which roots develop in it. The consolidation caused by punching holes is an advantage on light soils but a disadvantage on heavy soils. With all methods, however, it is important to plant firmly to ensure that the plants are quickly established.

In windy districts the plants may be set out for protection in shallow trenches about 4 in. deep. The shelter helps the establishment of the plants and the soil in the bottom of the trench does not dry out so quickly.

Supporting Plants

For single rows of standard varieties the best method is to drive stout stakes 5½ ft long to a depth of 18 in. at intervals of 12 ft along the row. A single wire

is strained tightly along the tops of the stakes, i.e., 4 ft above ground level, and another fixed 6 in. above ground level. Strings to support the plants are then stretched between the wires. As the plants grow the strings are twisted round the stems as in glasshouse practice. If canes are used for support, the lower wire is not required. The bottom of each cane is pushed into the soil, the top being tied to the top wire. The plants are tied to the canes with raffia or soft fillis.

For double rows, a stake or cane is inserted for each plant and each pair of canes is drawn together at the apex for fastening to a single wire supported as for single rows. Alternatively, crowding of the tops of the plants may be prevented by fixing cross pieces of wood, 18 in. long, to the tops of the end stakes. Wires are then fixed from the ends of these cross pieces and the canes tied to the wires.

Setting Fruit

Suitable conditions for setting are provided by high day temperatures and warm dewy nights. In these conditions a full set of fruit is usually obtained without any special treatment. Under less favourable conditions, the first truss may fail to set and, to avoid the resultant loss of fruit, overhead spraying during bright weather may be necessary. A hose pipe is often used for this purpose, the end being nipped so as to form a spray which is thrown from side to side over the plants.

Pruning, Trimming and Stopping

All side shoots of standard varieties should be removed as they develop and, in order to give free circulation of air, the lower leaves may also be removed when the truss of fruit immediately above is fully developed. This defoliation should be kept to the minimum. The leaves should be removed entirely, not shortened, by breaking them off or cutting close to the stem. The wholesale removal of leaves, aimed at getting the fruits to ripen more quickly, is ineffective and may cause considerable loss of crop.

Usually the plants are stopped by taking off the growing point two leaves beyond the third or fourth truss about the third week in July. Since it is difficult to ripen four trusses fully, even under the best conditions, the plants should be stopped at three trusses in less favourable districts. After stopping, one or two side shoots should be allowed to develop with the object of enabling the plants to use any surplus water taken up after rain, so preventing splitting of the fruit.

Bush varieties, as mentioned previously, do not require pruning or stopping. All growths may be allowed to develop, but sometimes the removal of weakly growths improves the fruit without reducing the crop.

Watering and Cultivation

It is not easy to give precise instructions for watering outdoor tomatoes, but the effects of too much or too little water can be stated. When the soil is too wet the plants produce luxuriant growth which turns soft in warm weather and becomes coarse under cool conditions, resulting in poor setting and small fruit. When the soil is too dry the skin of the fruit becomes hard, it is unable to extend rapidly and sudden heavy rain or copious watering causes the flesh to expand quickly and split the skin.

The ideal arrangement is an equable amount of moisture in the soil at all

times, and much can be done to maintain this by soil improvement and cultivation. Ball watering or light overhead damping is helpful in the early stages of growth. If watering of well-developed plants becomes necessary, as it will on light soils and in a dry summer, sufficient should be given at one time to ensure that the soil is moistened to a depth of at least 6 in. Overhead spray-lines provide an effective and economical method of application.

Cultivation after planting consists of hoeing to control weeds. With rows spaced as recommended, much of this cultivation can be done with a light tractor.

A light mulch of clean straw around the plants will help to prevent the soil drying out. In the case of bush varieties, a more adequate mulching will support the fruit and prevent it becoming dirty through contact with the soil.

The crop must be protected against blight, particularly in a wet season, by spraying with a proprietary copper fungicide at least fortnightly, from the time the disease may be expected to appear in the district to the final clearing of the fruit. (See also p. 80).

Fruit Ripening

With tomatoes grown in the open a proportion of the crop is usually still green when the plants have to be cleared, before cold weather in autumn prevents further ripening or causes frost damage. Any mature green fruit still on the plants at the end of the season can be ripened by cutting the trusses and spreading them out in single layers in a heated building. When blight has occurred, the plants should be sprayed at final picking time, before laying them out to ripen. Spray deposits may be left and the general appearance of the fruit is greatly improved by cleaning it and, although this operation may require extra labour at packing time, the better returns usually justify the cost. (See Fruit Ripening and Storing, p. 62).

Ripening of green fruit from an outdoor crop is frequently practised in an empty glasshouse. If stem rot is present, however, it is quite possible to introduce it into the glasshouse border through infected fruits, and under these conditions the practice is undesirable. (See Diseases and Pests, p. 78).

Picking, Ripening and Marketing

PICKING

The stage of maturity at which tomatoes should be gathered depends on the prevailing weather conditions and the period of time which is likely to elapse before the fruit reaches the consumer. When the crop is being sent to distant markets, particularly during hot weather, its condition should be much less advanced than when it is being sold direct to shops or when the weather is cool. Generally the development of an orange or orange-pink colour indicates the correct stage of maturity for sending to distant markets, whilst development to pinkish-red or full red may be desirable for local trade. The guidance given by the Tomato and Cucumber Marketing Board is that, "the fruit shall have reached a stage of maturity which will allow for ripening during the period normally required for distribution".

Picking early increases the difficulties of reliable quality grading, since certain blemishes, such as blotchy ripening and green back, may only become apparent when the colouring of the fruit is reasonably advanced. On the other hand, fully ripened fruit bruises easily in transit.

The demand for high quality fruit is increasing steadily and it is important to remember that many of the blemishes affecting quality can be caused by disease or unsuitable methods of cultivation long before the crop is ready for picking. After picking, the maintenance of quality is assisted by removing the fruit as soon as possible to cool, airy conditions, allowing it to stand overnight before packing if necessary and ensuring good ventilation on the way to market.

Tomatoes should be picked individually by breaking the stalk connecting the fruit to the truss at the joint immediately above the calyx, the calyx being retained on the fruit. The presence of a fresh, green calyx adds to the attraction and is an indication to a discerning purchaser that the fruit is freshly gathered.

The nursery routine should be planned so that picking can be done in the early morning when the fruit is cool, provided it is dry. The containers both before and after filling should be stacked in the shade. Care should be taken at all times to avoid bruising the fruit either during picking or when loading the containers on to the trucks for removal to the packing shed or grading centre. Containers which are to be handled without covers should not be filled to the top as bruising may easily occur. Picking should not be done immediately after watering and care should be taken to see that the containers do not become damp or dirty when the soil and plants are wet.

FRUIT RIPENING AND STORING

Green Fruit

The tomato is a sub-tropical fruit and is very intolerant of low temperatures during the ripening period. When the plants are cleared at the end of the season, particularly from an outdoor crop, the bulk of the fully-grown green fruit can be ripened over a period of several weeks by storing the fruit in a heated building. Fruit left on the cut trusses appears to ripen a little more slowly than detached fruit, taking up to a week longer at the normal temperatures for ripening. At 55°F fully-grown but green fruit ripens completely in about 5–8 weeks, but at 65°F it will ripen in a little over half that time. At temperatures below 55°F green fruit colours very slowly and poor quality with severe wastage from rotting is liable to result before the completion of ripening. Below 50°F green fruit is unlikely to ripen normally. Ripening can thus be hastened or retarded over a period of 2–8 weeks by adjusting temperatures between 55 and 70°F.

Near-ripe Fruit

Fruit that has been picked at the turning stage, i.e., just as the green colour turns paler and the first flush of orange is about to appear, normally ripens under warm conditions in a few days. The rate of ripening can, however, be considerably retarded by storing at 53°F. At this temperature the fruit will keep without loss of quality or abnormal wastage until the marketing stage is reached in about 2 weeks. Outdoor tomatoes ripen more slowly than a glasshouse crop.

If fruit is kept at a temperature below 53°F for too long, some of it fails to ripen normally, quality is poor and wastage from rotting heavy. It is risky to attempt to store at lower temperatures or for longer periods. Cool storage of ripening fruit should be regarded as a useful method for temporarily holding back supplies from an overloaded market in a glut period.

The following procedure should ensure that fruit can be held back with the minimum risk of wastage. Since the aim is to delay ripening for as long as possible fruit should be picked at the turning stage, stored promptly and cooled quickly to 53°F. It should be stacked in trays, small boxes (12 lb) or other suitable containers, or placed in shallow layers. An empty refrigerated apple store is suitable for cool storage, but whatever the type of building used it should have a moist atmosphere (about 90 per cent humidity) to prevent undue loss of weight and quality. If the fruit is stacked too closely or in large stacks or containers, it fails to cool satisfactorily and losses ensue. Slatted containers allow the free passage of air needed for rapid and effective cooling. Card or fibreboard containers are unsuitable, because the moist conditions in store soften the board and the loss of rigidity may result in collapse of the container and damage to fruit.

GRADING AND PACKING

Grading for quality is done by eye. It is possible to grade when picking, particularly when the crop is of uniform quality, but it is more usual to grade in a packing house either at a bench or from a moving belt. (See Fig. 5).

Grading for size can be done by eye or machine. Grading by eye is usually done at the same time as grading for quality. Skill and accuracy can soon be attained, especially if fruits of the required minimum and maximum size for each grade are set up as specimens.

There are a number of types of mechanical size-graders available, covering a range of capacities to suit most nurseries. Grading for quality and size is done as two successive operations on the same machine and the fruit then passes into the market containers.

The names of the grades follow the traditional practice of describing the quality and various size ranges by the colours of the lining papers used. For example "Pink", "Pink and White" and "White" describe first quality tomatoes in three different size ranges. "Pink" are large fruit and "White" small. "Blue" is commonly used to describe fruit which is of even colour but either too large or misshapen for classification into any of the three first quality grades. (Details of the grades in current use can be obtained from The Tomato and Cucumber Marketing Board, 10 Stanhope Gate, London, W.1.)

Although the market value of outdoor tomatoes may be lower than that of glasshouse crops, the way in which the fruit is handled and packed can help its sale. Since it is necessary to spray the plants for the control of potato blight disease, a spray deposit may be left on the fruit. The general appearance can be greatly improved by cleaning and, though the operation will probably require extra labour at packing time or the attachment of some form of cleaning unit to the sizing and grading machine, the better returns may justify the cost (see p. 77). On a small scale the fruit may be cleaned by hand-wiping or by tipping into a blanket and gently rolling it.

The 12 lb unit is recognized as the most suitable for the wholesale marketing of tomatoes. Containers should be rigid, easy to handle and adequately ventilated. Three types are in common use:

a wooden tray with corner posts (Dutch-type tray). A paper cover is frequently tacked over;

b cardboard basket with handle and lid;

c returnable quarter-bushel box.

These containers are the subject of constructional standards which have been drawn up by the British Standards Institution, viz:

Wooden Trays for Tomatoes. B.S. 2892: 1957.
Fibreboard Baskets for Tomatoes. B.S. 3200: 1960.
Bushel, Half-Bushel and Quarter-Bushel Boxes. B.S. 2568: 1955.

Copies are available from British Standards House, 2 Park Street, London, W.1.

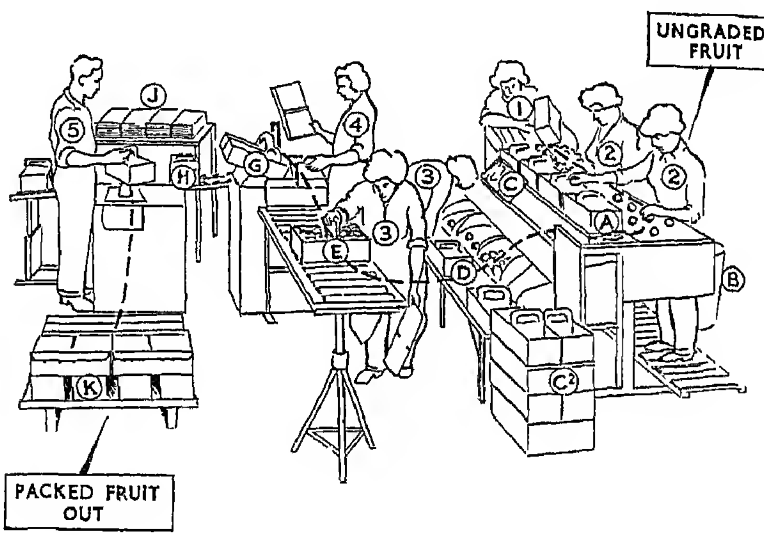


Fig. 5.

1. Feeding ungraded fruit to the grader from fruit stack at her left hand side. Stacking empties for re-use or transfer to C2. Replenishing boxes at C1.
2. Removing blemished, rough and second grade fruit to boxes at A. Waste fruit to bin B.
3. Transferring filled baskets from A and D to gravity roller E. Renewing baskets at A and D from C2.
4. Weighing on scales, making up from reserve baskets at G and transferring to gravity roller H.
5. Lidding from stock at J. Stapling lids on revolving platform and stacking on stillage K for transfer by pallet truck to lorry.

NOTE:

(a) The gravity rollers transfer the fruit and prevent waiting time by evening out the rate of flow. The number of workers at 2 and 3 depends on the quality of the fruit. The dotted line shows the path taken by the graded fruit.

(b) An alternative arrangement to the storage of empty boxes at C2 would be an overhead feed over position C1 supplied direct by operator 1.

The 12 lb chip basket is now less used than formerly, but the 6 lb chip is being used increasingly for the early crop.

When sent by rail tomatoes should be loaded into suitably ventilated trucks. Fibreboard containers should not be stacked more than four layers deep. When road transport is used plenty of air must be allowed into the load and with non-rigid containers steps must be taken to give some form of shelving support.

Seed Saving

ALL glasshouse tomato varieties grown in Britain have flowers with the style enclosed within the anther cone. Due to this structural feature it is virtually impossible to get natural cross-pollination. Straight varieties are naturally inbred and it is easy to maintain a pure line.

Seed saving is a simple operation and many growers save seed from their own crops when growing a straight variety. It must be emphasized that seed should not be taken from F_1 hybrid plants as these do not breed true. Seed of these varieties must be produced anew for each generation by cross-pollinating the two parents.

Plants chosen for seeding must be true to the varietal type and particular attention should be paid to vegetative habit, fruit setting, earliness, crop yield, fruit quality and disease resistance. The first selection is best made when the bottom truss is ripening and all desirable plants should then be numbered with a durable label. This choice should be reviewed as the season progresses. All fruit and seed should be labelled similarly to the plant from which it was taken so that the seeds from any selected plants which do not maintain their initial promise may be discarded. In this way the purity of the next generation will be maintained and contamination of a good stock by inferior forms prevented. Valuable new sports arise very infrequently and, if one is suspected in a crop, expert advice should be sought to confirm it. Growers who release to the market selections of dubious origin and merit cause a great deal of harm to the industry.

Fruit is picked when fully ripe, cut in two and the seed squeezed out into wooden or glazed earthenware containers. When handling large quantities it is preferable to pass the pulp through a $\frac{1}{4}$ in. sieve in order to separate it from skins or fruit walls. Hands and sieves should be washed clean of adhering seeds before beginning the next batch of fruit. Seed is extracted by one of three methods:

1. *Fermentation.* The seed pulp is left in a warm place for 5 or 6 days and stirred twice daily. The mucilage is broken down as the pulp ferments. The method is inconvenient because of the time it takes and some seeds may begin to germinate during the process.
2. *Hydrochloric Acid.* The seed pulp is mixed with one quarter its volume of concentrated (35–38 per cent) hydrochloric acid, stirred and left for half an hour. The method gives a very clean seed sample but the acid is

corrosive and needs to be handled carefully. This method is recommended as a means of inhibiting mosaic virus on the seed coat.

3. *Sodium Carbonate.* The seed pulp is mixed with an equal volume of 10 per cent solution of washing soda and left for 18–24 hours. This is a convenient method and gives a good seed sample.

After extraction by one of these methods the seed must be washed thoroughly and all debris removed. This is best achieved with a jet of water and two sieves, the first to pass the seed and the second to retain it.

The seed should then be spread in a single layer on sheets of clean glass and left to dry. In order to reduce the possibility of tobacco mosaic virus on the seed coat, it is recommended that fresh seed should be soaked in 10 per cent trisodium phosphate solution for 30 minutes and redried unless extracted by the hydrochloric acid method. During drying it should not be exposed to high temperatures, direct sunlight or the attention of mice When quite dry the seed is scraped off with a blunt knife, separated by rubbing between the hands and stored in cotton or paper bags labelled clearly with the variety and year of production. Airtight tins or jars are not suitable for seed storage.

When handling seed of different varieties great care should be taken at all times to avoid admixture and contamination.

Fourteen pounds of fruit yield about 1 oz seed which contains approximately 8,000 seeds.

Equipment and Mechanical Aids

This section deals with the principal items of mechanical equipment employed in tomato production, with the exception of soil sterilization and heating equipment which are fully covered in Bulletins No. 22: *Soil Sterilization* and No. 115: *Construction and Heating of Commercial Glasshouses*, respectively.*

Before any equipment is purchased it is essential to make sure that:

a the method of production being considered is the best in the circumstances;

b the capital expenditure and running costs are justified by the economies or better results which will be obtained;

c the type of equipment is the most suitable.

POTTING SHED EQUIPMENT

The first stage in plant production is the preparation of suitable seed and potting composts. These are made by mixing in definite proportions of shredded sterilized loam, peat and sand with the addition of small amounts of chemical fertilizers.

Soil Shredders

Where only very small quantities have to be handled the loam and peat can be broken up and sieved by hand. This method is too expensive in labour

* See Appendix III.

where larger amounts are needed, and under these conditions the provision of one of two basic types of mechanical soil shredder is worth while. In one type, a number of steel blades rotating at high speed inside a steel casing break up the loam or peat as it is fed in through a hopper. When the particles are small enough they are thrown out through a screen consisting of spring-loaded bars. In some cases the screen size can be adjusted. In the other type, the loam or peat is shovelled into a hopper at the bottom of which a wide endless belt, carrying rows of steel teeth, moves at high speed. The material being shredded is tumbled and combed in the hopper until the particles are small enough to pass under spring-loaded bars, when they are thrown out into a heap. The flexing of the belt as it passes over the rollers prevents blocking of the spaces between the teeth.

Soil shredding attachments for two-wheeled rotary cultivators are very much cheaper than shredding machines and are satisfactory where small quantities of shredded soil are required, but larger quantities justify the use of a special shredding machine. These are generally driven from their own electric motor or internal combustion engine, although some are designed to be driven from another power unit such as a tractor. While this reduces the initial cost of the shredder its use is limited by the availability of the power unit. Where a shredder with its own power unit is to be employed, one with an electric motor is usually cheapest and most convenient, provided that electricity is available near where the machine will be used.

Loam for shredding should be fairly dry and should not contain large amounts of undecomposed organic matter such as grass root fibre, otherwise the machine will become blocked and, particularly with some of the rotating bar types, wet soil results in the production of hard lumps which are quite unsuitable for composts. Dry peat can be broken up effectively with a soil shredder, the peat being moistened by a spray of water as it leaves the machine.

Compost Mixers

The correct proportions of the bulky constituents of a compost can be obtained easily with a measure such as a small truck or gauging box. This is an open-bottomed box fitted with handles and marked internally at levels which correspond to the required volumes of the ingredients. Sterilized loam is put in until it is level with the first mark, peat up to the second mark and sand, previously mixed with fertilizers, up to the top. When the box is lifted the ingredients are left on the floor ready for mixing. Where mechanical mixing is employed the compost must not be too wet as this will result in the formation of hard balls of soil.

Small quantities can be mixed satisfactorily by turning the heap several times by hand, but where large quantities are involved mechanical mixing is preferable because it reduces labour and generally results in more uniform mixing. Mechanical compost mixers are of the revolving drum type, similar to concrete mixers. In some of the smaller ones the drum can be rotated by hand, but power driven machines are generally preferred. Relatively low cost power-driven mixers are available which can be fitted on to and driven by some four-wheel tractors, one advantage being that the compost can be transported easily. Where a mixer with its own power unit is selected and there is a suitable electricity supply, an electric motor is usually the cheapest and most convenient form of power unit.

To ensure accurate mixing each batch of ingredients should be mixed separately, but where this is not practicable rough hand mixing should be done prior to mechanical mixing.

Where conditions do not justify the purchase of a compost mixer, satisfactory mixing of fairly large quantities can be done by a soil shredder, the ingredients being mixed twice by hand before being put through the machine. The shredder should be positioned so that it throws the compost at a wall, or a deflection plate should be fitted to reduce the grading effect due to the smaller particles falling near to the machine and the larger ones farther away. A secondary grading effect caused by the larger particles rolling down the outside of the heap can be reduced by levelling out the heap at intervals.

Soil Block-making Machines

While various types of pots and peat blocks have their own merits, soil blocks have many advantages and are widely used in the propagation of tomato plants. For making blocks the compost should not contain stones as these can cause stoppage of the machine with resultant loss of production.

Soil blocks are made by filling a mould with compost which is then compressed by a plunger. During the process a depression to take the seedling is made in the top of the block with a dibber. It is better to form the block round the dibber than to press the dibber into an already compressed block. Finally the block is ejected from the mould. The degree of compression should be capable of easy adjustment so that blocks can be produced which are just compact enough to hold together until they are bound by the roots.

Advantages are claimed for hexagonal or cylindrical moulds, but in practice there is little difference between the two shapes. In many cases interchangeable moulds of different sizes are available. For tomato production $2\frac{1}{2}$ or 3 in. moulds are generally the most satisfactory.

There is a wide range of soil block machines on the market varying in output and price. The lower output machines (200–800 blocks per hour) are manually operated, while electrically powered and operated machines are available which can produce 1,000–2,800 blocks per hour. Besides being capable of a greater output per hour and per worker, power-driven machines give a more consistent block than is obtained with a manually-operated machine which has to be used for long periods each day.

Soil blocks are made at a time when many other jobs need doing and when a machine is being chosen careful consideration should be given to the amount of labour needed to produce the supply of blocks for the season. A considerable saving in further handling can be made if on leaving the machine the blocks are put on to trays.

Artificial Illumination

This has been fully dealt with in the section on Propagation, p. 23.

MECHANICAL CULTIVATION

Whether the border soil has been sterilized and flooded or cropped prior to the planting of tomatoes, it will be necessary to cultivate the soil to bring it into the right condition for planting. Similarly at the end of the crop the

soil has to be cultivated for the following crop or in some cases for sterilization. Hand digging of glasshouse soils is still widely practised for a number of reasons, such as the difficulty of mechanical cultivation with many structural and pipe obstructions, the limitation of depth of cultivation with small rotary cultivators and the superior results obtained with hand digging of clay or silty soils. However, there are many cases where rotary cultivation of border soil can give very satisfactory results with a marked reduction in labour requirements and increased speed of operation.

The most common type of rotary cultivator used on nurseries is the two-wheeled type fitted with a petrol or diesel engine of 1–10 h.p. which drives a rotor as well as the wheels. The rotor consists of a horizontal shaft mounted at right angles to the direction of travel, to which is fixed a number of L-shaped blades or tines. These cut the soil and throw it upwards and backwards and other factors being equal a coarser tilth is produced with L-blades than tines. The rotor is covered with an adjustable hood. The type of tilth produced can be varied by adjusting the forward speed in relation to the speed of the rotor. A coarse tilth is produced by selecting a high forward speed and a low rotor speed. The width of the rotor varies from about 10 in. in the small machines to 30 in. in the large machines. The latter are more difficult to handle in confined spaces than smaller machines and, as they weigh 4 cwt or more, they are not easy to move over 4 in. pipes where these are some distance above the soil. Where a rotary cultivator is to be used in glasshouses, it is particularly important to select one which is well balanced and manoeuvreable. A recent development of particular value to those growers who have small glasshouses with many obstructions is the compact light-weight, medium-powered rotary cultivator. This machine weighs as little as ½ cwt and is fitted with an engine up to 4 h.p. The machine is moved forward by the action of the tines. Wheels are sometimes provided to assist in the movement of the machine from one place to another. The depth of cultivation, fineness of tilth produced and forward speed are all controlled by tipping the machine backwards or forwards. As these machines are light and are worked in an almost vertical position they are particularly suitable for use in confined spaces.

It is always wise to select a machine with an ample reserve of power, for a long, trouble-free life cannot be expected from a machine which is always worked at full capacity.

With modern glasshouses of wide span, few or no permanent obstructions and wide doors, rotary cultivators mounted on medium-powered, 4-wheeled tractors can be employed. These machines are able to cultivate the soil to a greater depth than the hand controlled cultivators, but even with these it is not always possible to cultivate to a sufficient depth for deep soil sterilization. Again the continued use of rotary cultivators can lead to pan formation in some soils. In such cases hand digging has to be employed.

WATERING EQUIPMENT

Soil moisture regime has a marked effect on type of growth, yield and fruit quality. Hand watering is used in the propagating stages with plants in pots or soil blocks, as it allows any unevenness in drying out to be corrected easily and the capital and labour cost is low. The fixed-pipe watering system is rapidly replacing hose watering in the cropping houses. It saves labour

and gives an increased crop because of the more uniform application of water, accurate liquid feeding, less panning of soil, elimination of damage from careless use of hoses, reduction of disease by maintenance of lower humidities and reduction in leaching of nutrients.

An efficient watering system must be able to maintain the moisture content of the soil in the plant root zone within set limits. It is therefore necessary to know how much water to apply and to have equipment which will apply it evenly. Accurate watering using appearance of the crop and soil as a guide requires a great deal of skill, experience and judgment and it would be helpful under present conditions if this could be replaced or supplemented by instruments which could be widely used.

A given soil moisture regime at a given point can be maintained by tensiometers. These indicate changes in the capillary tension of the soil moisture and are available in a form suitable for glasshouse use. Provided a grower uses a minimum of three instruments to give a cross check and takes care to site them and set them up properly, they give a useful and reliable guide to water application. Soil at field capacity gives a tension reading of about 3 cm of mercury. For tomatoes water should be applied when the tension rises to 7–10 cm, the porous pot being 6 in. deep and buried midway between plants. A development of the tensiometer which may provide a completely automatic watering control has the standard pot replaced by a quicker acting, more sensitive pot and the vacuum gauge by a vacuum switch, the differential operation of which is used to control the operation of an irrigation system.

Water loss from a crop is related to the solar energy falling on the leaves and this can be calculated from solar radiation measurements. A simple, cheap and reliable integrating photometer is at present available for about £30. It operates independently of a power supply and can be calibrated to give a direct reading of water requirement. Photometers are now being tested on Experimental Horticulture Stations.

Evaporimeters developed for the control of irrigation on outdoor crops can be modified for use under glass. The rainwater collecting gauge is removed and replaced by a graduated glass tube. As water is lost from the evaporating surface the copper dish is replenished from the tube which can be calibrated to give a direct reading of water requirement.

Where no instrument is available water requirement can be estimated from simple weather observations (see p. 42).

Watering Systems

There are two systems of watering, overhead watering and low level watering. While overhead watering with irrigation spray lines fixed to the roof of the glasshouse is successful with some crops, it is not widely used for tomatoes nor can it be recommended generally. When the plants become tall the foliage interferes with the sprays of water and this results in uneven distribution. In addition, the excessive humidity produced from this type of equipment can result in a marked increase in disease, particularly during dull, humid summers. In view of this low level watering systems are the most suitable for the crop. There are three principal types:

Trickle Irrigation

This was the first type of watering equipment to be widely employed,

In this method small diameter rubber pipes, fitted with special nozzles at the same distance apart as the plant spacing, are laid along each row so that there is a nozzle near each plant. Various types of nozzle are employed to give a very low output of water, generally less than $\frac{1}{3}$ gal per nozzle per hour. At these low rates of flow, water drips from the nozzles and is immediately absorbed by the soil where it spreads out below the surface to give a cone of moist soil. The amount of spreading which occurs varies with the rate and frequency of application and with the soil type, being greater with clay and less with sandy soils. The water is applied to the trickle lines from a main, which in turn is fed from a header tank, or directly from the mains if there is little fluctuation of mains pressure. In these cases pressure is controlled by adjusting the standpipe tap. A well designed system will give an even distribution of water on level ground and a reasonably even distribution where the ground slope is not excessive.

The Low Level Sprinkler System

This was designed at the National Institute of Agricultural Engineering and gives a greater zone of wetted soil than is obtained with trickle irrigation under some conditions. The system can be installed by a firm specializing in this type of work or made up from commercially available components. Full details are given in Horticultural Machinery Leaflet 3: *The Low Level Sprinkler Irrigation System for Use under Glass.**

In this system rectangular areas of soil are wetted by jets of water of variable length which issue from small holes drilled in rigid plastic tubes. A tube drilled with holes, spaced at the same distance as the plants, is laid on the path side of each row with the holes inclined upwards and inwards so that the jets of water cross each other. When the pressure of the water in the sprinkler line is high the throw of the jet will be longer than when the pressure is low. The pressure in the system is varied by adjusting the hand valve on the standpipe, so that for each watering in a cycle the jet falls at different points. The output per hole varies with pressure and hole size, so that with 0·024 in. diameter holes, which are recommended, the average output over the normal pressure range is about $\frac{2}{3}$ gal per hole per hour. All the sprinkler lines are connected to one or two mains which are in turn connected to the standpipe. The system gives a very even distribution of water on level sites but unless precautions are taken uniformity falls off quickly as the slope increases. There is not a great deal of difference in the initial cost of this system compared with the trickle system but, where a low level system has been assembled and installed by the nursery staff, the cost is less than for an equivalent trickle irrigation system. It is also likely to have a longer life.

Lay-flat Tube Sprinkler System

Another watering system which is cheap to install employs thin walled, lay-flat polyethylene tube usually punched with two rows of closely spaced holes. Where tomatoes are grown in double rows the tubes are laid on the soil between the double rows and connected to a distribution main which in turn is connected to the standpipe. When the water is turned on the tube fills with water, becomes roughly cylindrical and water emerges in

* See Appendix III.

jets from the holes. As with the low level sprinkler system the length of the jets can be varied within certain limits by adjusting the standpipe tap. While this method is considerably cheaper than the other two it has two disadvantages, a greater labour requirement and less uniform application of water. With the number and size of holes employed the rate of water application is high, and in most cases the amount of tube which can be used at once is limited to a short length by the amount of water available at the standpipe. Also if large applications of water are to be avoided each tube must be used only for a very short period, usually less than 10 minutes; thus during watering frequent attention is needed to control the flow to different lines in turn. As with all low level watering systems, uniformity of water distribution falls off as the difference in height between the lowest and the highest hole increases. Careful planning can minimize the effect of slope, but it is usually less accurate than with other methods, because of the generally lower operating heads which have to be employed with a single tube to water between double rows of plants and the relatively large volume of water contained in the tube which drains to the bottom end each time the system is turned off.

A filter should be included in all systems where nozzles with fine passages or holes are used. Where liquid feeding is to be practised the filter should be inserted between the diluter and the first nozzle.

Some means of measuring the quantity of water applied is essential if accuracy is to be achieved. Where the pressure head is always constant, e.g., in a trickle irrigation system fed from a nursery header tank without any variable pressure loss in the feed pipe, the application rate will be constant, and once this is known application can be based on time of watering with reasonable accuracy. If this system is adopted it is desirable to check the application by collecting the output from one nozzle. Where pressure head varies the best method of controlling application is by measuring with a water meter the quantity applied, although the collection of water applied to a given area or the use of a graduated header tank can be used as alternative methods. A water meter should be of the inferential type fitted on the upstream side of the diluter so that water containing fertilizers does not pass through.

DILUTING EQUIPMENT

The main advantages of liquid feeding compared with dry feeding are a saving in labour, rapid response, more efficient use of fertilizers and more accurate control of plant growth and salt concentration in the soil, provided that the nutrient solutions are used at concentrations appropriate to the rate of uptake by the plants.

Concentrated stock solutions for liquid feeding or chemical sterilizing agents which are applied with water have to be diluted to a given strength and intimately mixed with the water. While liquid feeding can be done with hose watering, accurate feeding can only be achieved with a system which ensures even application of the solution.

Dilute solutions are sometimes made up in the nursery storage tank and fed through the nursery water mains to the standpipes, but although this method has a low initial cost it is inflexible and not generally satisfactory. Because of this a number of diluters have been produced which can feed

concentrated solutions from a container into water flowing from the standpipe to give constant, accurate and easily adjustable dilutions. Provision is usually made for dilutions between 1:20 and 1:2,000, although with some makes ratios outside this range are possible. The lower ratios are employed for chemical sterilization while the medium and high ratios are used for liquid feeding.

Three main types of diluter are employed. In the Venturi diluter the concentrated solution is drawn into and mixed with the main flow of water by the negative pressure produced when the water flows through a special pipe constriction called a venturi. This system was employed in several commercial diluters in the past but, with the development of other types which are generally more accurate and reliable, it is not now widely used.

With charge diluters the concentrated solution is displaced from a closed container into the main by an equal quantity of water which is drawn off from the main and fed into the container. The dilution ratio is controllable over a wide range by varying the rate of water flow into the container. This is done by adjusting a special valve or by fitting jets of different sizes. In one type of charge diluter there is no physical barrier between the water and the solution but, because of the greater density of the solution and the low rates of displacement, there is definite layering with little intermixing. In the other type the water and solution are separated by a flexible diaphragm so that no intermixing can occur. The single compartment type is the cheaper of the two and, provided it is used with reasonable care, satisfactory results can be obtained.

Pump diluters consist of a positive displacement type of water meter inserted in the water supply line; the meter directly drives an adjustable stroke piston pump which draws the concentrated solution from a container and injects it into the water. This arrangement gives a very constant rate of dilution which is independent of water flow, but the units are very much more expensive than charge diluters; because of this they are generally justifiable only where the annual use is high. The quantity of water delivered is often indicated on a dial and hence no other equipment is needed to measure application rates.

Where a number of glasshouses are cropped identically as a single unit labour, and in some cases capital, can be saved by feeding a group of houses from a single diluter. The watering systems in each glasshouse are connected through plastic mains to the diluter unit. Valves on each system are adjusted to balance the flow of water, while control of watering and feeding for the whole unit is at one point. The size of such a scheme is limited by the water supply available and the capacity of the largest diluter.

EQUIPMENT FOR THE CONTROL OF PESTS AND DISEASES

Pests and diseases can spread very rapidly in a tomato crop unless prompt and effective action is taken. For the treatment to be effective the active material must be correctly chosen and applied uniformly over the whole of the plant surface, and in some cases over the soil and structure surfaces as well. Greater uniformity of cover is required for the control of diseases than for the control of mobile insects and where foliage is dense great care is

needed to achieve uniform and complete cover. Active material can be applied as a spray, a dust or a vapour.

Spraying is the most common method employed at present. Applications can be in the form of high volume, low volume or a compromise between the two. In high volume spraying the active material is applied in a dilute form until all the surfaces are completely wetted. This method usually gives the most uniform cover but large quantities of water, up to 400 gal per acre, are needed. Labour costs are higher than with other methods and with the foliage remaining wet for a long time after spraying work in the crop is unpleasant. Spray droplets in high volume sprayers are produced by forcing the liquid under pressure through a special nozzle. The pressure is produced either by a manually or mechanically operated pump at the time of spraying or by air pressure which is built up in the spray tank before spraying. There is a wide range of equipment on the market but, whatever type is selected, it is important to see that adequate provision is made for the easy cleaning of all parts which are in contact with spray materials.

In recent years low volume spraying has been adopted on some nurseries to overcome the difficulties encountered with high volume. In this method a small quantity of concentrated active material is applied in the form of very small droplets which dry quickly. The droplets are carried by a stream of air and in order to get effective deposition the air stream must be directed on to the crop. If the spray is directed into the air in a glasshouse very little chemical will be deposited on the crop and what is applied will be unevenly distributed. Skill and care are needed to obtain uniform application with this method, but good results can be achieved with a considerable saving in time and labour compared with high volume spraying.

Three basic types of low volume spraying machine are used in glasshouses:

Spinning-disc Sprayers and Aerosol Generators

Generators of these types have been used to produce mists of spray in glasshouses for a number of years. Although there are variations in detail, the basic principle of atomization employed in all types is to feed the concentrated spray fluid from a container on to a high speed rotating disc, very small droplets being produced as the fluid is thrown off the periphery of the disc. As the droplets are produced they are carried away in an air stream produced by a fan driven from the same motor as the disc. The relatively slow moving air stream can be used to move the foliage of plants and assist even distribution of the droplets on all surfaces. Units powered by an electric motor or a small petrol engine are available. Electric-powered types are light enough to be carried by hand, but the petrol driven types have to be supported on a single-wheeled frame or shoulder-mounted. A wheeled unit is not as manoeuvreable as a shoulder-mounted one, particularly where rows of plants run across the house, but the operation is less tiring and the operator has better control of application. Although the petrol engine-driven units are heavier and larger than electrical powered units they can be used on indoor and outdoor crops.

When a machine is being chosen the type of spray formulation which will be used should be carefully considered. In some cases it has been found that with formulations containing a volatile solvent evaporation results in crystallization of the active material on the disc, while the particles in

suspensions and emulsions can be centrifuged out. In both cases there is a loss of active material and the deposition of solid materials on the machine can cause blockages which affect performance.

Air-atomizing Sprayers

In recent years a number of types of small low volume air-atomizing sprayers have come on the market. These are usually shoulder-mounted and driven from a small petrol engine. A high speed air stream, which is directed over the nozzle assembly, breaks up the spray fluid into fine droplets which are carried in the air stream. Care is needed in using these machines in glasshouses as the high velocity air stream can cause serious physical damage to plants if the nozzle is held too close to them. Some machines of this type can be converted quite easily into dusters and like the petrol engine spinning-disc sprayers they can also be used on outside crops. At the time of writing the air-atomizing sprayers are slightly more expensive than spinning-disc units.

Compressed-air Gun Sprayers

Although no detailed comparisons have been made of the different types of low volume sprayers for glasshouse use, observations suggest that this is the best method.

The equipment consists of a spray gun, air hose and air compressor. The gun is similar to those used for paint application except that the metal container is replaced by a glass jar which provides the operator with a visual check on the application rate. The gun chosen should be easy to clean and handle and should possess adjustments to allow both the liquid and air supply to be varied to suit different conditions.

The size and length of air hose needed is determined by the length of the glasshouse and the number of guns to be operated from the hose. It is normal to use only one gun from each hose and in this case it has been found that $\frac{3}{8}$ in. internal diameter is suitable for hoses 200 ft long. The rate of working is considerably improved and the life of the hose increased if a hose reel is used. With a reel fitted with a swivel-coupling the hose can be paid out and wound back without interrupting the air supply.

The air compressor should be capable of delivering 7 cu. ft of air per minute per gun at a pressure of not less than 60 lb per sq. in. A pressure reducing valve which allows adjustment of air pressure at the gun is a desirable feature. Generally a portable compressor is required. An electrically driven unit is preferable but where electricity is not readily available at all the operating points a petrol engine-driven unit is needed.

Dusting can be carried out with this equipment by substituting a powder gun for the spray gun, but in this case it is essential that a moisture separator should be fitted to ensure that the powder is kept quite dry.

Compressed-air spraying equipment is two or three times the cost of the other two types of low volume sprayer and in some cases, particularly on the smaller glasshouse units, its purchase cannot be justified. Besides spraying and dusting in glasshouses this equipment can be used for several other jobs on the nursery, such as tyre inflation, paint spraying and operation of automatic ventilation systems; the value of these other applications should be taken into account when cost is being considered.

TRANSPORT AND GRADING OF FRUIT

Transport

At present almost the whole of the tomato crop is carried out of glasshouses by hand although various attempts have been made to do this mechanically. Mechanization of this operation is not easy and carrying by hand is likely to continue as the principal method employed for some years to come. The distance to the nearest outside door of the glasshouse has an effect upon the work involved in removing the crop. Doors should be provided at both ends and very long glasshouses should be avoided. Where exceptionally long houses are to be rebuilt it is generally worth while taking the opportunity to provide more frequent access points. This can be done by inserting doors down the side of the house as well as at the ends or by dividing the house into two with a roadway. The second method reduces labour requirements as well as improving ventilation and the evenness of heat distribution, and is therefore the best method where blocks of houses are concerned.

On the small nursery transport of fruit from the glasshouse to the packing shed is often done with hand barrows or trucks and, where short distances and small quantities are involved, this is probably the most satisfactory method. The same equipment is suitable for the transport of other materials and equipment about the nursery.

On the larger nurseries mechanical handling can result in a worthwhile saving of labour. Various types of equipment can be used, but pallets or stillages and tractor-mounted transporters are probably the most widely used at present. In this system pallets or stillages are loaded with boxes of fruit at convenient points near the glasshouses and transported by tractor to the packing shed. In the packing area the fruit can be brought up to the grader and the graded and packed produce taken away on pallets or stillages which are moved with the aid of hand trucks. Where the lie of the land permits the easy construction of a loading dock lorries can be loaded at dock level, but where a dock does not exist elevators or other types of lifting equipment are necessary if the produce is to be loaded mechanically.

No hard and fast rules can be laid down on the best method of handling produce but the method and equipment should be chosen in each case with the particular conditions in mind.

Grading

Before despatch tomatoes are graded for quality and size. On nurseries with a small output both operations are normally done together manually. In these cases the use of a well designed sorting table and a good method of working enables reasonable output to be achieved per worker at a very low capital cost. Where larger quantities of fruit have to be handled sizing by machine is often justified. The full benefit cannot be achieved from mechanical sizing unless the machine is correctly integrated into the whole process of grading, packing, weighing and despatch of fruit. The layout should be planned so that each worker makes as few useless movements as possible. In many cases a simple roller conveyor system can give considerable improvements in labour utilization.

Where mechanical sizing is adopted the fruit is quality graded by hand before sizing by the removal of poor quality fruit on the feed tray or on a

special belt conveyor. In the latter case the fruit is usually fed on to the belt over a chat-eliminator which reduces the number of fruits to be inspected.

There are a number of types of grader on the market with outputs to suit most nurseries, ranging from about 500 to 5,000 lb per hour. The principle employed for sizing consists of moving the fruit mechanically over apertures of increasing size. In practice sizing is achieved by feeding the fruit:

- *a* on to diverging belts or diverging plain or helical rollers;
- *b* on to a moving base which rolls the tomatoes against a bar whose distance from the base increases; or
- *c* over a series of circular apertures of increasing size.

A number of factors affect grading accuracy but, other things being equal, accuracy will increase as the number of diameters measured during sizing increases. Other points which should be considered carefully when choosing a machine include output, labour requirement, number and range of sizes, general construction, ease of maintenance, adjustment and cleaning and damage to the fruit. The majority of machines give at least five size grades, the graded fruit usually being collected directly in market containers.

Electricity is the most convenient form of power for graders. The power requirement is usually about ¼ h.p. although in high output machines 1 h.p. may be needed.

Some machines can be fitted with combined cleaning and polishing attachments. These consist of a conveyor which carries the fruit under a series of revolving brushes. These units are expensive, particularly for the smaller grading machines, and at present it would seem that the additional cost cannot always be justified.

Diseases and Pests

Brief descriptions of the chief symptoms and routine methods of control for the commoner diseases and pests of tomatoes are given in the following paragraphs; further information on some of them will be found in the Ministry's Advisory Leaflets.* It is essential that the troubles should be correctly diagnosed and when in doubt growers are advised to consult the National Agricultural Advisory Service.

DISEASES

Damping-off and Foot Rot

A number of soil fungi, including species of *Phytophthora* and *Corticium solani*, may cause damping-off of young seedlings or a foot rot of older plants. The fungi enter through the roots or penetrate directly into the stem at soil level, the tissues decay and the plant collapses.

Usually infection takes place from the soil but it can occur from boxes, pots or a contaminated water supply. Soil used for propagating should always be sterilized, preferably with steam (see Advisory Leaflet 319)*

* See Appendix III.

and the boxes and pots disinfected with formalin. Epidemics of damping-off can often be stopped by watering the boxes with Cheshunt compound or a proprietary copper fungicide as soon as the trouble begins.

Root Diseases

Root diseases are associated with a number of fungi, including *Colletotrichum atramentarium*, *Thielaviopsis basicola*, *Corticium solani* and *Fusarium* spp., but the presence of any of these organisms usually indicates that soil conditions are unsuitable for normal root development. Faulty drainage, root damage when potting or planting out or chilling of the roots by transplanting when temperatures are low may be the primary cause.

Careful attention to drainage and all cultural operations will do much to prevent the occurrence of these troubles. Severe wilting, associated with root rot, sometimes occurs just before picking begins and the crop can often be saved by adopting the following procedure. The houses should be shaded, all ventilators and doors shut and the plants damped overhead 3 or 4 times a day. The surface of the soil should be covered with a layer of good peat, about 1½ in. thick, and kept well watered. Sphagnum is best and very acid peat is harmful. After about a week the plants begin to form new roots and in 10 days or a fortnight the peat will be permeated by clean white roots. Provided they are supplied with suitable fertilizers, these roots are able to take over the functions of the old decayed root system. Damping can then be stopped and ventilators opened.

Verticillium Wilt

This disease, caused by the fungus *Verticillium albo-atrum* (see Advisory Leaflet 53: *Tomato Verticillium Wilt**) is usually severe only when temperatures are low. Under some conditions wilting can be sudden and the plant withers within a short time and dies. It may progress slowly under conditions less favourable to attack: yellow blotches appear on the lower leaves, later spread upwards and the leaves eventually wither. Plants affected early in the season may be stunted. A characteristic feature of the disease is a brown discoloration of the woody tissues extending some distance up from the base of the stem.

When only a few plants are affected they should be removed and burned. If a large proportion of the crop is affected the house should be shaded, the air kept moist by overhead damping and the soil fairly dry. The temperature of the house should be maintained at about 77°F for a fortnight, after which the normal routine can be resumed. This treatment is not a cure but it often enables the plants to recover sufficiently to produce a reasonable crop. At the end of the season all the infected plants should be burned and the soil in which they were growing must be steam sterilized before another crop is planted in it.

Stem Rot and Fruit Rot

Attack by *Didymella lycopersici* is often destructive of outdoor and glasshouse tomato crops. Mature plants suddenly wilt and on the main stem just above soil level a dark brown sunken lesion is found. Sometimes leaf

* See Appendix III.

spotting occurs. Infected fruits develop a black rotted area at the stem end. Fruits are often severely attacked especially in the open.

The soil used in propagation should always be sterilized and canes, seed boxes, pots, etc., which have been in contact with infected plants must be disinfected. As the fungus can be carried in the seed, diseased fruits should not be used as sources of seed. Diseased plants should be removed from the house as soon as discovered and burned, and at the end of the season sulphur should be burnt in the house and the soil sterilized. Lesions on the stems caused by *Didymella* should not be cut out as infection can be spread from plant to plant on knives or hands: they should therefore not be confused with *Botrytis* lesions which can often be successfully trimmed off. In outdoor crops, after removal of infected plants, the stem bases of adjacent plants may be painted with 1·5 per cent maneb, although there is some risk of injury to the plants.

Grey Mould

Grey mould is caused by the fungus *Botrytis cinerea* which enters the plant through pruning wounds, leaf-scars, etc., and spreads from them into the stem causing a grey-brown lesion. Sometimes the flowers are attacked and wither prematurely. The affected parts usually become covered with a fluffy grey or brown-grey mould growth, consisting mainly of *Botrytis* spores which are soon blown about and reach other, still healthy, plants. They may settle on the fruits and under humid conditions produce the well-known water spots. These spots, which are often found first on the green fruits, appear as minute raised brown spots surrounded by a circular zone of normal colour and then by a zone of very pale green. The fungus usually dies soon after penetration and the spots do not enlarge, but sometimes the whole fruit becomes affected by a soft rot.

To control grey mould it is essential to provide adequate ventilation. As the fungus grows abundantly on decaying plant material all dead leaves, etc., should be removed and burned. Infected portions of stem should be trimmed off flush with the stem and the wounds painted over with a paste of tecnazene, salicylanilide or captan, or with creosote.

Leaf Mould

Leaf mould (see Advisory Leaflet 63: *Tomato Leaf Mould**), caused by *Cladosporium fulvum*, is first noticed causing yellowish patches on the upper surface of the leaves. These spots become covered on the undersides with a brownish growth of fungus spores and mycelium.

In many houses adequate ventilation gives satisfactory control. Where the disease recurs every year chemical sprays may be needed, but must be applied as soon as, or if possible before, *Cladosporium* is seen in the crop. Freshly precipitated zineb (nabam and zinc sulphate) has given good control even when conditions have favoured the fungus. Salicylanilide, copper or sulphur sprays may be effective in controlling mild or moderate attacks. A number of resistant varieties have been developed, but unfortunately none is resistant to all the physiologic races of the fungus occurring in this country, and probably only Eurocross, Syston Cross, Antimold B, J.R.6 and Sapford's No. 1 can be recommended for general use.

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* See Appendix III.

Blight

Tomato Blight (see Advisory Leaflet 271: *Potato and Tomato Blight**) is caused by the same fungus (*Phytophthora infestans*) which causes potato blight. It is not usually serious under glass but in some seasons is very destructive on unsprayed crops in the open. Black-purple areas appear on the leaves and stems and in damp weather the margins of these areas become covered with a white, downy growth. The fungus also attacks the fruit causing large, dark brown blotches. Spraying with half-strength Bordeaux mixture or with colloidal copper, or dusting with copper dusts effectively controls the disease. Zineb or nabam and zinc sulphate are also used.

Buck-eye Rot

This trouble chiefly affects the fruit of the bottom two trusses and is caused by a soil-inhabiting fungus *Phytophthora parasitica*. Affected fruits show reddish-brown patches on which arise a series of darker brown concentric rings.

Lower trusses should be tied up to keep them off the ground and watering should be done carefully to avoid splashing. Mulching the surface of infected soil or spraying the ground and lower portions of the plant with Cheshunt compound also helps to prevent infection.

Mosaic

Mosaic (see Advisory Leaflet 38: *Mosaic Disease and Streak of Tomato**) is very common and is caused by the tobacco mosaic virus which exists in a number of different strains and produces a variety of symptoms. The most characteristic symptom in spring and summer is a pale green or yellowish mottling of the leaves accompanied by some curling and distortion. In winter stunting and distortion are more pronounced and "fern leaf" symptoms are frequently present. The fruits are often blotchy when half ripe. When the severe "streak" form is present, dark streaks appear on the stems, leaf stalks and sometimes on leaves and the fruit may have discoloured markings. As the disease spreads rapidly it is important to eliminate sources of infection and young plants showing suspicious mottling should be destroyed. Frequently infection is spread by handling first infected and then healthy plants; in order to prevent this all healthy plants should be attended to first. As the virus is sometimes present in smoking tobacco, workers should not smoke while handling plants and should wash their hands with soap and hot water before starting work. Preferably seed should not be saved from infected plants.

Double Virus Streak

This disease is caused by joint infection with two viruses, tomato mosaic and potato virus X. It is rarely found in crops under glass but frequently occurs where tomatoes are grown in the open near potatoes.

The disease is first observed in the top leaves, which turn pallid and show numerous brown or black lesions, and longitudinal dark sunken streaks appear on the main stem. In severe infections the entire top of the plant may become necrotic resulting in die-back from the tip. Fruits of affected plants sometimes show irregular brown spotting.

* See Appendix III.

Spotted Wilt

This virus disease (see Advisory Leaflet 238: *Tomato Spotted Wilt**) is often present in nurseries where ornamental plants are also grown. The first symptom is that the upper leaves tend to curl downwards and inwards. Very soon they become bronzed and the growth of the plant is arrested. The fruit may show a pale irregular mottle or distinct concentric yellow-brown circles.

All affected or suspicious looking plants should be removed and destroyed. Tomatoes should not be grown in houses with perennial ornamentals, especially chrysanthemums and dahlias. Thrips, the insects which transmit the disease from plant to plant, can be kept in check by the application of DDT or gamma-BHC.

Cucumber Mosaic

This disease (see Advisory Leaflet 340: *Cucumber Mosaic**) is particularly troublesome on outdoor tomatoes. The leaves become narrow, producing the "fern leaf" or "shoe string" symptoms, and the crop is severely reduced. In glasshouses the disease is easily controlled by regular fumigation with an insecticide to destroy the aphids which spread the virus (see p. 86). Outdoors the virus is usually brought by aphids from infected perennials to tomatoes. Outdoor tomatoes should therefore be planted as far away as possible from dahlias, delphiniums, lupins, primulas, etc.

Blotchy Ripening

This is a condition in which certain areas of the fruit fail to ripen properly. Unripened patches occur anywhere on the fruit while the remainder reddens normally. All varieties appear to be susceptible though some tend to suffer more than others. The trouble is essentially a seasonal one and in some years may be severe. The cause is not yet understood, but there is evidence to show that its appearance follows periods of high day temperatures and very bright weather. Vigorous crops tend to be the worst affected and the aim should be to prevent excessive rise of day temperatures and to produce a balanced plant.

Bronzing

This name is given to a disorder of tomato fruits in which a light brown colour shows through the skin of the fruit while it is still green. The brown colour is caused by a necrosis of the cells around the vascular tissue. In slight attacks fruits show no external lesions, but on the surface of severely affected fruits irregular brownish, slightly sunken lesions are found, while the same browning of the tissues just below the skin can be seen on cutting. The disorder may be associated with various factors including soft, unbalanced growth, high day temperatures in spring, low night temperatures, excessive watering, heavy shading and low nutrients. Current work suggests that some fruit bronzing symptoms are due to infection by tobacco mosaic virus.

Green Back

Frequently the stalk end of the fruit does not colour normally but remains green. The trouble may be attributed to exposure to strong sunlight or to shortage of potash.

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* See Appendix III.

It can usually be prevented by leaving sufficient foliage to shade the fruits and by ensuring an adequate supply of potash.

Blossom End Rot

This is a physiological trouble ultimately due to a deficiency of available calcium. Many factors can affect the availability to the plant of soluble calcium: in particular a high concentration of salts or an excess of one specific nutrient may induce a deficiency of it and unfavourable moisture conditions can also play a part. Externally the symptoms appear as a dark green circular patch at the tip of the fruit. Later this patch becomes brown or black, shrunken, flattened and leathery in texture. Because a particular outbreak may involve one or more of many factors, advice should always be sought on control measures.

Oedema or Dropsy

Greyish-white, furry blisters or ridges appear on the under surfaces of the leaves, on the leaf stalks, truss stalks and sometimes on the main stem. The trouble is induced when the water uptake by the roots is in excess of the amount that the leaves can eliminate in the usual way by transpiration. This occurs when the soil is warm and very moist and ventilation and light inadequate.

PESTS

This section gives notes for the grower on most of the pests, including all the important ones, that attack the tomato under glass. Particular attention is drawn to the more serious pests, namely, potato root eelworm, root knot eelworm and red spider mite: glasshouse whitefly and symphylids might also be included here, the others are of minor importance.

General accounts of some pests are given in the Ministry's Advisory Leaflets referred to in this text and listed in Appendix III. The majority of the chemicals mentioned for the control of pests are available in the form of proprietory products officially approved for the uses and at the rates given with other directions on the makers' labels. The use of approved products where appropriate is strongly advised (see Appendix IV).

Potato Root Eelworm

This pest (*Heterodera rostochiensis*) attacks tomatoes as well as potatoes and is serious in many glasshouses. Occasionally it is present with root knot eelworm and it may then escape notice. It does not cause definite galls, although infested roots may show slight local swellings. Attacked roots become unnaturally branched and contorted and on careful inspection white or brown cysts, each about the size of a poppy seed, can be seen attached to the roots.

Potato root eelworm most frequently occurs on tomatoes under glass as a result of building glasshouses on infested land, growing early potatoes in the houses from seed from infested land (thereby introducing cysts either on the sets or in attached soil), or replacing the soil in the glasshouse with soil from an infested field.

Tomatoes infested with potato root eelworm are retarded in growth to an extent depending on the severity of infestation. The foliage wilts in

sunshine, the leaves of affected plants are darker green than normal and the trusses may be much reduced. In severe attacks the lower leaves develop necrotic or dried-up areas and die off and the first truss fails to develop.

Steam sterilization is the most effective method of control. Chemical soil treatments can, however, provide a useful degree of control. They enable the interval between successive steamings to be extended, or may replace it entirely if soil conditions are favourable. This subject is discussed under Chemical Soil Treatments, p. 87.

Root Knot Eelworm

These eelworms (*Meloidogyne* spp.) are widespread pests of tomatoes grown under glass (see Advisory Leaflet 307: Root Knot Eelworm in Glasshouses*). Several species infest tomatoes but for practical purposes they can be treated together, since their effects on the plants are similar and they can only be distinguished by a specialist.

Root knot eelworms enter the root and cause nodules varying from a pin's head to a walnut in size. Often the nodules coalesce to form a distorted misshapen mass of roots. Moderate attacks retard growth, reduce yield and cause slight wilting of the foliage during sunny periods. In severe attacks the foliage turns yellow and withers and the plants may die.

Where steam sterilization can be applied so that every part of the soil is heated to 210–212°F to a depth of 2 ft a satisfactory control is usually obtained. Normal steaming prevents attack early in the season but is not likely to eradicate the pest.

Good control of root knot eelworms can be obtained with chemicals applied to the soil by injection, watering on, admixture by rotary cultivation or a combination of these procedures. More details are given under Chemical Soil Treatments on p. 87. Whatever material is used, adequate time must be allowed between treatment and planting and the maker's directions must be followed carefully. Chemical treatments are generally less costly than steaming.

When steam or chemical sterilants are used special care must be taken to treat the soil round walls, dollies, etc., and where it is warmed by hot water pipes.

If an attack is first noticed in the growing crop, a mulch with moist peat about 1 in. deep may be given and kept moist so that new roots will grow, thus enabling the plants to continue growth and mature a crop.

Red Spider Mite

The red spider mite (*Tetranychus urticae* syn. *T. telarius*) is a widespread and serious pest of tomatoes (see Advisory Leaflet 224: *Red Spider Mite on Glasshouse Crops*). The active summer forms of this species are green but they turn bright red if starved or stimulated by lower temperatures and shorter daylight length to become winter forms. Another species, *T. cinnabarinus*, which has reddish-brown summer females and does not hibernate, may occasionally be found on tomatoes, although it is more usually associated with perennial plants. The adult mites are just visible to the naked eye. *T. urticae* lays white eggs and *T. cinnabarinus* brown eggs. A whole succession of generations is completed from the end of April, each taking 13 days at 70°F, but as few as 6 days at 90°F.

* See Appendix III.

The mites can be detected during the early stages of attack by the yellow speckled markings which appear on the undersides of the foliage. The yellow mottled leaves rapidly become dry and, if unchecked, the mite population increases so rapidly that food becomes scarce and the mites spin masses of thick webbing over the foliage to form cocoons. Under such conditions injury to the plant is usually fatal.

As most infestations are initiated by mites emerging from winter hibernation within cracks and crevices of the greenhouse structure, the crop should be removed from the houses in late summer while still in a reasonably healthy state. Stimulation to hibernation is largely dependent on plant nutrition and, if food is plentiful, the mites will remain in their summer form even when the day length is limiting. Following prompt removal of the crop disinfection and fumigation is recommended before the mites have reached their hibernating sites.

To control red spider mites on young plants in the propagating house, or on recently planted tomatoes with soft growth, it is safest to apply high volume sprays of Kelthane at 8 oz of 20 per cent concentrate per 100 gal together with a wetting agent, dimethoate at 16 fl. oz of 40 per cent concentrate per 100 gal, or demeton-methyl at 12 fl. oz of 50 per cent concentrate per 100 gal.

There must be an interval of at least 7 days with dimethoate and 21 days with demeton-methyl between application and fruit picking.

Two applications of parathion smokes at an interval of 8–10 days will normally give a good measure of control if the temperature is kept at about 70°F for at least 4 hours from the commencement of smoking.

Attacks on well-established plants can be controlled by high volume spraying (300–600 gal per acre) with Kelthane or diazinon (16 fl. oz of 20 per cent concentrate per 100 gal), or dimethoate when picking will not start for at least 7 days after application. From the end of May onwards Kelthane, fenson, chlorfenson, chlorbenside and diazinon aerosols produced from atomizing concentrates can be used, provided temperatures of about 70°F can be maintained for several hours after their application. Smokes containing azobenzene or azobenzene plus parathion will give satisfactory control of normal mites if repeated at 5–10 day intervals.

There must be an interval of at least 2 days between applying diazinon aerosols and picking fruit.

The control of red spider mites may be complicated by the existence of strains resistant to certain chemicals. The alternate use of organo-phosphorus compounds, such as diazinon, dimethoate and demeton methyl, with Kelthane, fenson, chlorfenson or chlorbenside, is suggested as a precaution to reduce the likelihood of producing resistant strains.

Glasshouse Symphylids

These are fragile, white, centipede-like animals up to about ¼ in. long living in the soil (see Advisory Leaflet 484: *Glasshouse Symphylids**). They are sometimes numerous in tomato houses, particularly when the rotation includes lettuce. The chief injury is to the roots of seedlings and to young plants soon after planting. The affected plants grow slowly, the younger leaves turn dark green or bluish and eventually the lower leaves turn yellow.

* See Appendix III.

When lifted the root system is very stunted and the symphylids can sometimes be found by letting them float out of the soil and roots in a bucket of water. Since symphylids move up and down in the soil according to conditions they are often not detected. Also the young ones are easily confused with certain harmless species and with harmless springtails.

Symphylid infestations usually build up over several years from small beginnings. They are extremely difficult to eradicate because of their migrating habit, which results in a reservoir surviving in the subsoil out of effective range of chemical and steam sterilization. With growing crops early confirmation of trouble is the first essential. A very good kill of symphylids can be obtained by watering the plants soon after planting out with a pint per plant of a drench containing 1 fl. oz of 20 per cent parathion in 10 gal water. Twenty per cent liquid diazinon at the same dilution is less poisonous than parathion, but carries a slightly greater risk of damaging the plants.

Glasshouse White Fly

The moth-like glasshouse white fly (*Trialeurodes vaporariorum*) is about 1/25 in. long, white in colour owing to a covering of white wax and is very conspicuous especially in flight (see Advisory Leaflet 86: Glasshouse White Fly). This pest is widely distributed. The eggs, which are attached by stalks to the leaves, are laid usually in circular groups on the lower foliage and are barely visible to the naked eye. The transparent, scale-like nymphs (young wingless forms of the insect) hatch in 12 days at 60°F but as few as 6 days at 75°F. After crawling about for a few hours they anchor themselves to the underside of the leaf and remain motionless until the adult fly emerges from the scale-case. The life cycle lasts 30 days at 60°F but is shortened to 20 days at 75°F. The nymphs and adults suck sap from the leaves, but little or no discoloration of the foliage is caused at first. The young insects, however, excrete large amounts of a sticky substance known as honeydew, which covers the leaves and fruit. Brown moulds subsequently grow on the honeydew and interfere with the functioning of the leaves which may be killed in severe attacks.

The glasshouse white fly may survive the winter on perennial plants in the vicinity of glasshouses and will continue to breed within the houses if suitable plants are available. Control of this pest can be quite difficult, especially if an infestation is allowed to develop, as the insecticides which it is possible to use on tomatoes only affect the adults and young larval stages. There is, therefore, continued emergence of adults from the unaffected pupae so that control measures will need to continue for some time to bring an infestation under control.

Two or three treatments with parathion smokes at intervals of 7–10 days should be used to control white fly on seedlings and recently potted plants. Plants well established in 3 in. pots can safely be sprayed with parathion (8 fl. oz of 20 per cent concentrate per 100 gal) or malathion (30 fl. oz of 60 per cent concentrate per 100 gal), or treated with DDT smokes. Several applications at 10–14 day intervals may be necessary.

Tomatoes established in their final positions can be sprayed with DDT (2 pt. of 20 per cent concentrate per 100 gal) or malathion, or the more convenient but somewhat less efficient application of these substances as aerosols may be adopted.

There should be an interval of 7 days between the application of malathion and fruit picking.

Aphids

Severe infestations of greenfly may occur on young tomato plants especially if they follow lettuce grown in the same house. Later in the season infestations of the glasshouse potato aphid (*Aulacorthum solani*) may build up, causing orange patches to appear on the leaves and discoloration of the fruit. This is in the form of mottling, large dark spots and oedematous patches which may not show until after the aphids have migrated from tomatoes. Gamma-BHC, diazinon, malathion and parathion all give control in smoke or aerosol form.

Mice

Damage to seedling tomatoes is sometimes noted early in the year. Usually mice eat out the hearts of seedlings leaving only the cotyledons. They are also recorded as picking out seeds from the seed boxes and gnawing ripe fruit. Break-back traps suitably baited or warfarin bait, set out as soon as suspicious seedling injury is seen, should prevent further trouble.

Tomato Leaf Miner

Severe attacks of this leaf miner (*Liriomyza solani*) have been recorded on young tomato plants. The adult is a small yellow and black fly, very active and inclined to settle on the sunlit leaves. The flies emerge from pupae in the soil in January and lay their eggs in the cotyledons and seedling leaves. They are rarely noticed unless very numerous, but their presence is shown by small rounded pits on the leaves caused by their feeding. Later the grey marks made by the larvae mining within the leaves makes the pest unmistakable. The fully grown larva pupates either in the leaf or in the ground.

An early infestation is not always followed by later attacks but, when two or more generations are produced, almost every leaflet may be mined by the end of August. Nevertheless this has little effect on yield. The important thing is to prevent damage to the seedlings because this can seriously affect growth and cropping.

If the previous tomato crop was attacked, a new infestation can only be prevented with certainty by steam sterilization of the soil. This destroys the pupae.

Frequent light applications of pyrethrum powder or treatment with parathion smoke gives some protection to young plants. Gamma-BHC sprays are more effective as they destroy the grubs in the mines, but they damage young plants and should not be applied to tomato plants less than 15 in. high before about mid-May. Two or three sprayings of gamma-BHC at 16 fl. oz of 10 per cent gamma-BHC miscible liquid in 100 gal water at 14 day intervals may be required to eliminate the pest.

Tomato Moth

The skeletonizing of the lower leaves is the typical feeding injury due to young caterpillars of this moth (*Diataraxia oleracea*). Later large holes are eaten out of the leaves and fruits by the bigger caterpillars.

The tomato moth is a common wild species throughout Britain. Infestations on tomato probably arise from the chance entry of moths into the glasshouses.

If the pest is already established in the propagating house, emergence of moths from pupae in the soil may begin in mid-January and go on until May. Outdoor bred moths emerge in June and July. The moths are plump bodied, dark brown in colour and active at night; they may be seen in daylight when the plants are disturbed or at dusk and afterwards if lights are on.

The eggs are laid in packed groups on the undersides of the leaves and incubate for 10–14 days. The brownish caterpillars develop in 5–8 weeks reaching a length of about 1½ in. before burying themselves in the soil to pupate. A new generation emerges after 3–4 weeks (in June or July) and produces a second generation of caterpillars, most of which stay in the chrysalid stage and give rise to moths in the following year. As a rule wild moths have only one generation of caterpillars which form chrysalids in late summer or autumn.

Satisfactory control is given by DDT in spray, dust, smoke or aerosol form. In the propagating house a dust or smoke may be used, as sprays and aerosols may harden the plants. To control an infestation occurring when picking is due, an aerosol or smoke should be used. These leave less residue on the fruit than dusts or sprays, which are also difficult to apply efficiently when the plants are tall and the foliage dense.

Wireworms

Wireworms (Advisory Leaflet 199*) may destroy young tomato plants. Attacked plants wilt suddenly and, on lifting, the stem at ground level is found to be holed. Losses usually occur either in houses up to 4 years after being put up on infested land, or when infested soil is brought in. If wireworms are found on a new site advice should be sought from the National Agricultural Advisory Service on whether or not chemical treatment is justified. A good control is given by broadcasting 1¼ per cent aldrin dust at 1½–2½ cwt per acre, working it into the top 4 in. of soil. If the growing crop is being damaged it can be watered with either gamma-BHC (16 fl. oz of 10 per cent gamma-BHC miscible liquid) or parathion (8 fl. oz of 20 per cent parathion liquid in 100 gal water). Parathion should be used if the soil drainage is such that water does not drain away more or less immediately; there is a risk of the gamma-BHC fluid injuring the stems if it lies round them in pools.

Woodlice

Woodlice bite through the stems and eat the tops of seedlings, occasionally destroying large numbers. They are not usually common in glasshouses which are kept tidy and in good condition. Numbers can be reduced by dusting their hiding places with gamma-BHC dust. Boxed seedlings may be watered with parathion as for wireworms and symphylids.

CHEMICAL SOIL TREATMENTS FOR CONTROLLING EELWORMS IN TOMATO HOUSES

Soil Fumigants

These are volatile materials which must be injected into the soil. Their action depends on the rapid diffusion of toxic gas from each point of injection. DD mixture (dichloropropane-dichloropropene) is widely used in

* See Appendix III.

commercial glasshouses and has proved of value where steam sterilization would be impracticable. However, control of eelworms — especially potato root eelworm — is unlikely to be complete, so it is better regarded as a means of lengthening the interval between successive steamings than as an alternative. Its efficiency varies a good deal with local conditions but correct preparation of the soil is also important. It is usually injected to a depth of 8 in. at a rate equivalent to 400 lb per acre. The soil at the time of treatment should be in good tilth and moist without being too wet; good seedbed condition is probably the best description of what is required. Sealing the surface after injection, by applying water or a liquid nematicide, will probably improve control. The National Agricultural Advisory Service can advise on the procedure best suited to local conditions.

The optimum soil temperature for fumigation with DD is about 60°F, so it is an advantage to inject immediately after tomato plants have been lifted while the soil is still relatively warm. In colder conditions, at least a month should be allowed before reworking the soil to encourage dispersal of fumes. Instances of taint of tomatoes by DD mixture have been reported on heavy soils.

Soil Sterilants

Materials such as formaldehyde and cresylic acid are being largely replaced by new materials, particularly those based on metham-sodium (sodium methyl dithiocarbamate). This breaks down on contact with soil moisture producing a toxic vapour, and has the advantage of killing fungi and germinating weed seeds as well as eelworms. Results against potato root eelworm are very promising and for control of this eelworm metham-sodium appears to be rather better than DD.

Metham-sodium preparations should be applied strictly according to the manufacturers' directions. They may be either injected as a concentrate in much the same way as DD mixture, diluted and watered on the surface or applied by a combination of both methods. Rotavation, following watering on or injection, is sometimes recommended to bring about rapid incorporation with the soil and this is likely to improve efficiency. With injection alone the vapour may not reach all parts of the soil, and on some soils surface drenching is difficult because of ponding which leads to uneven distribution below the surface.

If possible winter flooding should be carried out before treatment with metham-sodium and a sufficient time allowed afterwards for the soil to dry out to a moisture content similar to a seedbed or potting-compost.

The manufacturers' instructions must be followed carefully especially as regards time of treatment and after care. Ample time must elapse between treatment and planting the next crop because the vapour is very injurious to plants, especially tomatoes. Treatment should generally be made before the end of October. After treatment, keep the ventilators closed for about 2 weeks and then open them wide and fork over the soil to assist dispersal of the fumes. It should, however, be borne in mind that toxic fumes may easily spread into other houses through ventilators, ducts, doors and so on.

Several other compounds of the same general type as metham-sodium are likely to become available in this country in the future.

Chloropicrin, more commonly known as tear gas, is used extensively in Holland as a glasshouse soil sterilizing agent. So far it has been used only on

a limited scale in Britain, but when carefully applied and in sufficient dosage it has given encouraging results in the presence of a number of soil-borne diseases and pests, including root knot eelworm. In trials at the Glasshouse Crops Research Institute the yield of tomatoes from plots treated with chloropicrin were next highest to those obtained by steam sterilization.

It is normally injected into the soil at 12 in. staggered spacings to a depth of 6 in. and with the injection gun set to deliver 3.5 cu. cm per stroke; this is equivalent to 34 gal per acre. In difficult cases higher dosages may prove justified.

The vapour is very toxic to growing plants and in the winter months it may be necessary for a period of 6–8 weeks to elapse before crops can be planted with safety. In summer, on the other hand, a waiting period of 2 weeks has been known to be sufficient for the fumes to clear. A respirator must be worn by the operator.

For further details of this method of treatment Bulletin No. 22: *Soil Sterilization**, should be consulted.

HOUSE CLEANING

Some form of cleaning and disinfection of the houses is advisable when they are empty, especially where diseases and pests have been troublesome. Flowers of sulphur at the rate of 1 lb per 1,000 cu. ft may be burned in the empty houses. The vapour is capable of destroying the spores of *Cladosporium fulvum* (leaf mould). Burning is made easier by placing the sulphur on wood wool or similar material, which is then ignited. Sulphur should not be burned in houses treated with paint containing zinc, because water dripping from the roof will injure the plants. Galvanized wires should be well hosed down after the house has been fumigated.

Formaldehyde (1 gal of 40 per cent solution to 49 gal water) may be relied upon as a good general disinfectant when diseases have been troublesome. It should be applied with considerable force by means of a spraying machine, placing the nozzle near the surface of the roof, walls, etc.

Empty glasshouses can be fumigated by a potassium permanganate–formaldehyde treatment. Thirteen oz permanganate of potash are used per receptacle and 25 fl. oz of commercial 40 per cent formaldehyde are poured on. One receptacle with these quantities is sufficient to fumigate 6,000 cu. ft.

PRECAUTIONS

Some of the chemicals mentioned in this chapter for disease and pest control are scheduled poisons, others are not. As a general practice, whenever chemicals are used read and follow carefully the advice on the labels. The more poisonous chemicals, e.g., parathion, are included in the Agriculture (Poisonous Substances) Regulations, which are designed to protect agricultural workers by specifying, among other things, the protective clothing to be worn. Users of chemicals, whether these are scheduled as poisons or not, are strongly advised to read the Ministry's leaflet APS/1, *The Safe Use of Poisonous Chemicals on the Farm*, obtainable free from the Ministry of Agriculture, Fisheries and Food, (Publications), Ruskin Avenue, Kew, Surrey.

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* See Appendix III.

Appendix I

QUANTITIES AND SPACE REQUIRED FOR PLANT RAISING

Requirements per acre of glass

No. of plants: 14,000 per acre
Quantity of seed: $2\frac{1}{2}$ oz (about 8,000 seeds are contained in 1 oz)
Seed boxes (for sowing): 66 boxes required

66 boxes (2 in. deep) at 300 seeds per box

$7\frac{1}{2}$ bushels of compost needed (at 1 bushel per 9 boxes)

58 sq. ft staging occupied

18,000 seedlings for pricking out (allowing 10 per cent wastage for failures and weak seedlings).

Soil blocks or pots (for pricking out): 18,000 required, including reserve plants. The following quantities are based on large blocks requiring 1 bushel of compost per 80 blocks. 18,000 blocks require:

11 cu. yd compost (225 bushels at 20 bushels per cu. yd)

1,125 sq. ft staging if packed close for seedling illumination (144 blocks per sq. yd).

9,000 sq. ft of staging when spaced out for either pot or block grown plants, i.e., 2 plants per sq. ft of staging.

John Innes Compost: 1 ton of compost contains about 36 bushels.

Appendix II

Temperature Conversion Table

°C	°F	°C	°F
30·0	86	18·3	65
29·4	85	17·8	64
28·9	84	17·2	63
28 3	83	16 7	62
27·8	82	16·1	61
27·2	81	15·6	60
26·7	80	15·0	59
26·1	79	14·4	58
25·6	78	13 9	57
25·0	77	13 3	56
24·4	76	12·8	55
23·9	75	12·2	54
23·3	74	11·7	53
22·8	73	11·1	52
22·2	72	10·6	51
21·7	71	10·0	50
21·1	70	9·4	49
20·6	69	8 9	48
20 0	68	8·3	47
19·4	67	7·8	46
18·9	66	7·2	45

Formulæ for conversions

Centigrade to Fahrenheit.

$(°C \times \frac{9}{5}) + 32$

Fahrenheit to Centigrade:

$(°F - 32) \times \frac{5}{9}$

Appendix III

OTHER MINISTRY PUBLICATIONS ON TOMATOES AND RELATED SUBJECTS

Bulletins

22. Soil Sterilization. 4s. 0d. (by post 4s. 4d.)
115. Construction and Heating of Commercial Glasshouses. 6s. 0d. (by post 6s. 6d.).
123. Diseases of Vegetables. 7s. 6d. (by post 8s. 1d.)
138. Irrigation. 7s. 0d. (by post 7s. 6d.)
143. Salad and other Food Crops in Glasshouses. 4s. 0d. (by post 4s. 5d.).

Obtainable from H.M. Stationery Office, or through any bookseller.

Advisory Leaflets

38. Mosaic Disease and Streak of Tomato
53. Tomato Verticillium Wilt
86. Glasshouse White Fly
199. Wireworms
224. Red Spider Mite on Glasshouse Crops
238. Tomato Spotted Wilt
263. Tomato Leaf Mould
271. Potato and Tomato Blight
284. Potato Root Eelworm
307. Root Knot Eelworm in Glasshouses
319. Soil Sterilization
340. Cucumber Mosaic
360. Outdoor Tomatoes
375. Cloche Cultivation
465. Design and Cropping of Mobile Glasshouses
471. Seed and Potting Composts
484. Glasshouse Symphylids

Single copies, up to a maximum of six different leaflets, can be obtained free from the Ministry of Agriculture, Fisheries and Food (Publications), Ruskin Avenue, Kew, Richmond, Surrey. Quantities of more than six may be purchased from H.M. Stationery Office, price 3d. each (6d. by post), or through any bookseller.

Fixed Equipment on the Farm Leaflets

15. Shelter Belts for Farmland. 1s. 6d. (by post 1s. 9d.)
44. Design of Horticultural Packing Sheds. 6d. (by post 9d.)

Horticultural Machinery Leaflets

1. Glasshouse Heating Systems. 6d. (by post 9d.)
2. Boilers for Nursery Use. 6d. (by post 9d.)
3. Low-Level Sprinkler Systems for Use under Glass. 6d. (by post 9d.)
4. Fuels and Firing Equipment for Nurseries. 6d. (by post 9d.)
5. Pumps and Pipe Work for Heating Systems. 6d. (by post 9d.)

Obtainable from H.M. Stationery Office, or through any bookseller.

Appendix IV

CROP PROTECTION PRODUCTS APPROVAL SCHEME

Official approval has been granted in the Agricultural Chemicals Approval Scheme to a number of proprietary brands of certain of the insecticides and fungicides mentioned in this publication. Approval is indicated on the containers by the mark shown here. A list of the products approved will be published in February each year and can be obtained free of charge on application to the Ministry of Agriculture, Fisheries and Food (Publications), Ruskin Avenue, Kew, Richmond, Surrey. It is recommended that approved products be used.

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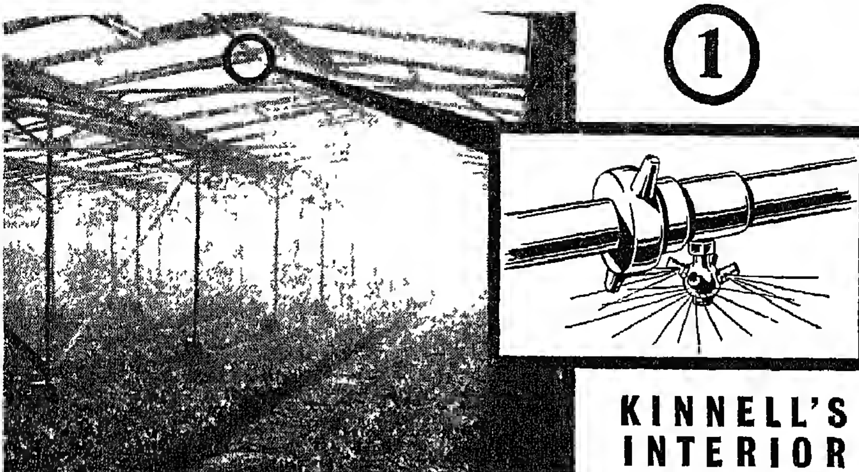

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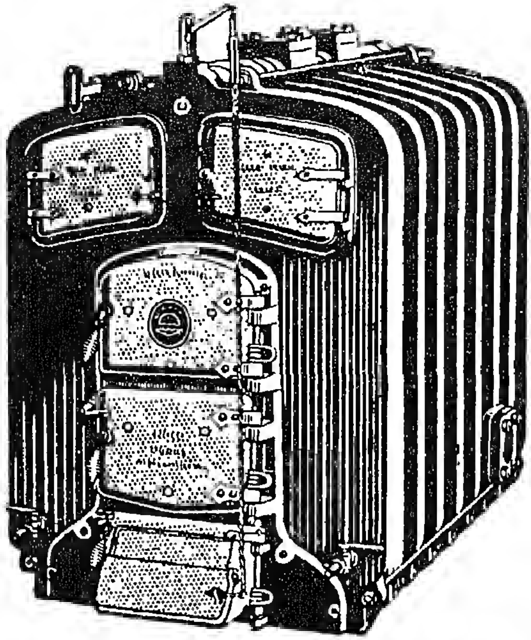

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